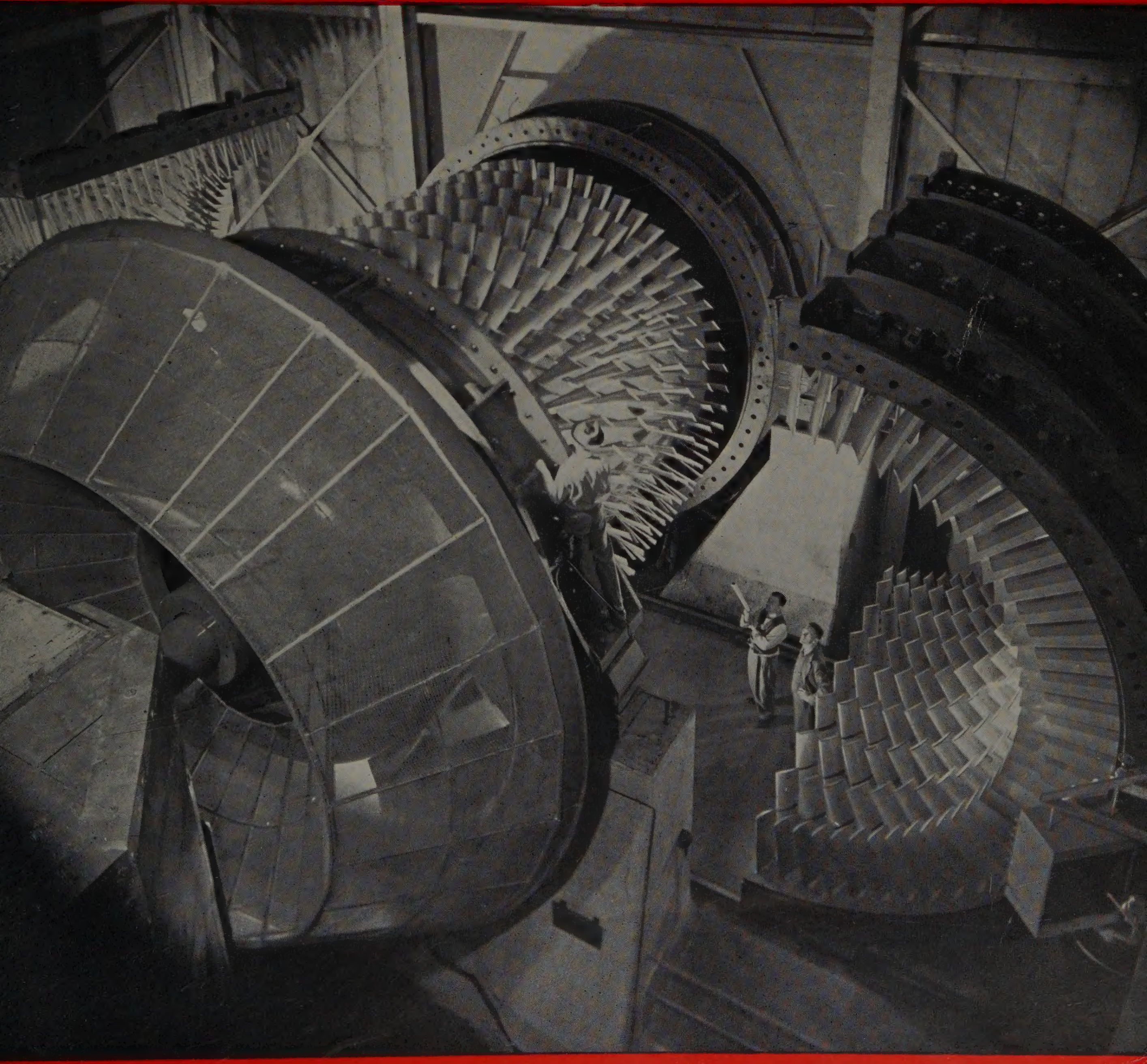
ELECTRICAL ENGINEERING

FEBRUARY 1952



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ELECTRICAL ENGINEERING

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FEBRUARY 1952

The Cover: The axial-flow compressor in the 8- by 6-foot supersonic wind tunnel of NACA's Lewis Flight Propulsion Laboratory is shown. See story by K. D. Brumbaugh on pages 118–23 of this issue.

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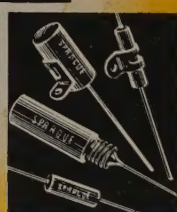
SPRAGUE SUBMINIATURE PAPER CAPACITORS



Hermetically-sealed, metal-encased and far smaller than equivalent JAN styles. Available in types for 85° C. and 125° C. operation. Sprague Bulletin 213-B gives full technical data.

COMPARISON—TYPICAL SUPER-JAN VERSUS JAN UNITS

Metal-Cased Tubular Paper Capacitor, Both Leads Insulated from Case

	Sprague Type 196P47492S1	Nearest JAN-C-25 Equivale CP25A1EC504K
Capacitance (Mfd., ± 10%)	0.47	0.50
Voltage, DCW	200	200
Insulation Resistance: at 25°C	30,000 M Ω*	6000 M Ω
at 85°C	700*	600 M Ω
at 125°C	20*	**
Capacitance Change (%) From 25°C to −55°C	−4*	−15
Operating Ambient (°C) Max.	+125*	+85
Minimum	−55	−55
Dielectric Test	Twice Rated Volts for 2 Min.	Twice Rated Volts for 1 M
Life Test: at 85°C	250 hrs., 1.5 × rated DCWV	250 hrs., 1.5 × rated DCW
Life Test: at 125°C	250 hrs., 1.4 × rated DCWV*	**
Moisture Resistance	Hermetically Sealed	Hermetically Sealed
Length	1-9/16*	2-1/8
Diameter	9/16*	3/4
Volume (cu. in.)	0.39*	.94

* Ahead of and Beyond JAN

** Above Temperature Limit of JAN-C-

SPRAGUE

PIONEERS IN
ELECTRIC AND ELECTRONIC DEVELOPMENT

SPRAGUE ELECTRIC COMPANY • NORTH ADAMS, MASSACHUSETTS

HIGHLIGHTS........

The Human Engineer. The job of the human engineer is to see that the task to be performed is kept within human bounds by presenting information that can be understood rapidly and accurately and by facilitating proper responses. Further, to insure a sustained high level of performance such factors as motivation and fatigue have to be kept in mind (*pages 107–12*).

Some Limitations of Science. The crisis we face today comes from the greed of men and their will to power regardless of conscience. The responsibility for the crisis is man's refusal to submit his behavior to reason and to reason's God, says T. E. Murray of AEC in this searching and profound article (*pages 123–25*).

Electric Power for Jet-Engine Research. The power distribution system of the Lewis Flight Propulsion Laboratory is described in this issue. Severe load demands and the tremendous expansion of the aircraft research facilities have presented some unusual problems which call for close cooperation between utility and customer (*pages 118–23*).

Aeolian Vibration in Overhead Ground Wires. When the Oklahoma Gas and Electric Company found numerous broken strands in its extra-high-strength steel overhead ground wires only a few months after their installation, a thorough investigation of contributing factors was begun. The pertinent details of the installations, location with respect to prevailing winds, the terrain, and the nature of the failures are described (*pages 128–32*).

A New Automatic Telephone System. Sweden's Telephone and Telegraph Administration is installing a common control automatic crossbar telephone system which can be used in all sizes of offices having over 100 numbers. It features a high degree of reliability and relatively low initial cost so that it is suitable for rural and semirural offices (*pages 134–39*).

Detection of Slot Surface Discharge. The nature of slot surface discharge between coil surfaces and core on high-voltage stator windings and the development of detection equipment are described. The discharge analyzer has been used extensively in a maintenance inspection program and provides for a relatively simple test requiring only a source of a-c test voltage of sufficient capacity to charge the stator winding under test to its normal operating voltage stress (*pages 143–47*).

Slot Discharge Detection During Operation. Basic work on generator slot discharge detection has shown that this disturbance is most readily detectable in the audio-frequency range. The present work is an effort to simplify the detection problem by using frequency-sensitive equipment across the generator neutral impedance. This method so far has proved very satisfactory (*pages 149–51*).

Butyl Insulation for Outdoor Use. Butyl compound has several outstanding characteristics that make it suitable for outdoor insulation: low moisture absorption, good corona and sunlight resistance, excellent adhesion to copper, low power factor, and good mechanical resistance. Its use on an outdoor instrument transformer is described (*pages 182–86*).

Electron Tube Experience in Computing Equipment. For several years tests have been conducted on the electron tubes used in the IBM computer SSEC as to their functioning and life expectancy. A description of the various tests, their results, and the effect on the economy of operation are given (*pages 154–57*).

Series Capacitors for Power Lines. The successful use of series capacitors in certain Swedish power line installations has aroused a greater interest in their use in the United States. This article discloses some of the important factors in the design of capacitors for series use (*pages 112–16*).

Gas Clean-Up in Arc Discharges. This interim report on the study of gas clean-up describes a new gas-discharge tube with a movable cylindrical probe used to study the clean-up effects of a tantalum surface bombarded by positive helium ions (*pages 159–64*).

Simplified Subtransient Reactance Measurement. A method is offered for measuring the subtransient reactances of large synchronous machines without uncoupling the turbine and with the rotor in any stationary position whatsoever. Only three sets of readings are taken, and from these the subtransient reactances are calculated (*pages 167–70*).

Effect of Unit Size on Generating Station Design. As system sizes increase and more interconnections between systems are installed, there will be a continued trend toward the use of larger generating units. Substantial savings in investment cost per kilowatt and operating cost per kilowatt-hour can be realized by the use of larger machines (*pages 174–79*).

Industrial Standards for Defense Production. Some representatives of important Government agencies are working with ASA only on a liaison basis. Industrial standards are so important to both the military and industry that these representatives should have the same status as members of other organizations who belong to ASA (*pages 187–88*).

News Index

AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions*.

AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student members, Affiliates, Associate Members, Members, and Fellows.

All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
Mar '51, p 35A	Winter General
Jul '51, p 23A	Southern District North Eastern District Great Lakes District Summer General
Nov '51, p 37A	Pacific General Fall General

Membership in the American Institute of Electrical Engineers, including a subscription to this publication, is open to most electrical engineers. Complete information as to the membership grades, qualifications, and fees may be obtained from Mr. H. H. Henline, Secretary, 33 West 39th Street, New York 18, N. Y.

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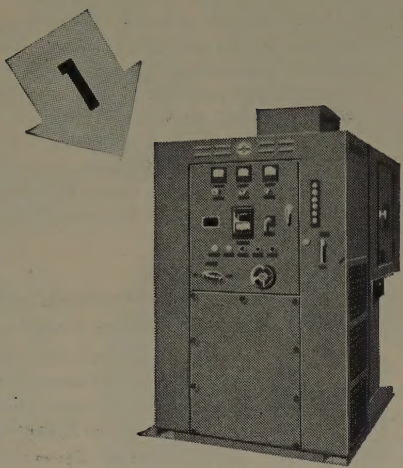
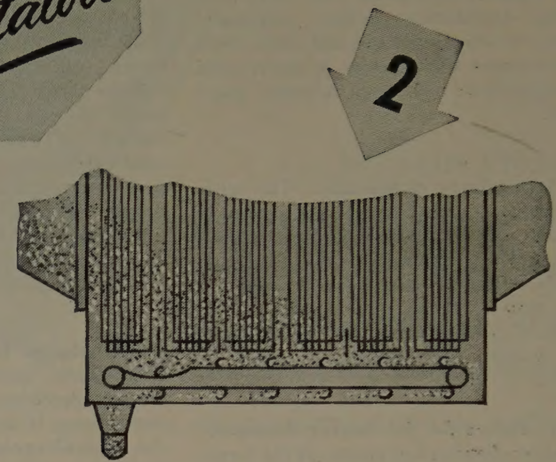
Let's be practical about precipitators



This Koppers "packaged" mechanical or vacuum tube power pack is not restricted to an area near the precipitator. It can easily be installed in any convenient place in the plant. Result: Compact designs! More flexibility!



This Koppers exclusive—the bottom drag scraper—provides continuous dust removal. Cumbersome hoppers are eliminated and dust handling is simplified. Result: Lower operating costs! Less space requirement!

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IN ADDITION to high efficiency, Koppers concentrates on the practical aspects of electrostatic precipitator design. Shown above are just two of the many practical features which simplify operation.

Besides these compact power packs and the continuous dust removal features, Koppers-Elex electrostatic precipitators may be of the multiple-chamber type. This means one chamber may be shut down for inspection or maintenance without stopping the gas-cleaning action. The dirty gas is simply diverted through other chambers where cleaning continues.

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The Human Engineer: New Ally for the Electrical Engineer

J. W. DUNLAP

This article deals with the interrelation of engineering with considerations of psychological and physiological behavior. This field, commonly referred to as "human engineering," has attained significance with the increasing complexity of technical machinery.

TODAY, MAN HAS FEW waking moments during which he does not make contact with some contribution of the engineering profession to his work, well-being, or comfort. Even now, engineers are brooding and stewing over new complex and fantastic devices which will make this world a better place in which to live. Engineers, as a group, are imaginative people, able to find practical solutions for involved problems. Taken as a group, they rank at or near the top of the population in intelligence, ingenuity, and creativeness. These very gifts are, in another sense, mankind's curse, for their possessors forget that others may not be so fortunate and that which may be simple to them is often difficult for others to understand and operate.

Unfortunately, once they have applied their creative touch, they move on to other work, and leave the everyday operation of their brain children to ordinary people, some of whom are dull, some alert, some slow, and some quick. From here on, it is performance, not brilliance of design, that pays off. The imagination and brilliance which have been invested in design may not be appreciated by those who make use of the machine. The only thing that counts is how well the machine and the man or men who operate it perform as a team.

With every step taken in pushing back the frontiers of knowledge, engineers are able to find new and better ways of extracting goods and pleasures from the natural environment. In doing so, their products tend to become more complex and more demanding on those who must use them. Not only is faster and more accurate operation required to keep up with the high performance capabilities of new equipment, but there are more jobs to be done, more instruments to watch, and more controls to manipulate. With a higher premium on speed, there comes a heavier cost for error; and, with increasing complexity, the difficulty of operation quickly approaches the physiological and psychological limits of the human member of the man-machine team. While technical changes have been occurring at a furious rate, the human machines are essentially the same today as they were three decades or three centuries ago. Man can be tuned physically and mentally, but physiologically and psychologically the characteristics of a given individual remain substantially constant. It is these limitations of the human member of the man-machine system with which the human engineer is concerned. If the man-machine team is to be maximally efficient, the human member must be given tasks within his capacity to perform.

THE HUMAN COMPONENT

BEFORE GOING FURTHER, it might be well to examine briefly the human component of the system. Man might be likened to a highly adaptable machine, but this adaptability is offset by his low efficiency in certain operations. The basic senses are very limited as to the amount of information they can provide for the decisions which must be made. Consider temperature. Man can classify temperatures as very cold, cold, cool, lukewarm, hot, and very hot. Provided certain conditions of temperature and conductivity are satisfied and a standard of comparison is set up, he can make finer discriminations which follow the Weber-Fechner law. Nevertheless, for several centuries the engineers have provided man with machines far more "sensitive" to temperature and far more reliable than his own senses. Other sense mechanisms are actuated by sound or light waves, and in turn control the actions, or feedback, of man, the machine.

One of the best examples of engineering inventiveness lies in the field of aeronautics, as evidenced by the tremendous increase in the number of displays and controls provided for the human members of the man-machine team. Early commercial aircraft carried fewer than 40 instruments and controls requiring pilot attention. Most of these were basic flight instruments. Today, the cockpit of a modern transport plane has more than 1,000 instruments and controls, each competing against all the others for the attention of the pilot. To be sure, most or all of these can be said to serve some useful purpose. The addition of another instrument may present to the pilot one more item of information which he should know, but not without penalty to the others in terms of pilot attention and comprehension. The pilot has just so much attention and perceptive ability to offer. Each additional dial that he must watch means that he must spend a little less time watching other dials and performing other tasks. In the final analysis, the objective of the instrument designers is to tell the pilot a story in such a way that he can best fly his airplane—not to invent a gadget for displaying information.

Today the addition of a single new information display

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in the cockpit presents a serious problem as to location. Originally, one looked for an empty spot on the instrument panel and put the new gadget there. The demands placed on the pilot today raise a whole series of questions: Where should the new gadget be placed? What is its relative value? Shall it displace another gadget? If so, which? Which are the most critical instruments? Should they be arranged in a group? If so, what grouping? Shall we group our information displays by function, by operational sequence, or by some other system in order to simplify the demands placed on the operator and maximize the joint efficiency of the man-machine combination?

Inputs and Outputs: Essentially, man is a complex of mechanical, chemical, and electrical systems; and, like any machine, he receives inputs from the environment in which he lives. Consider a man driving a car. The view he sees through the windshield may be thought of as a visual display of information which can be broken down into input members, control members, and background.

In simple situations, there may be only one or two inputs and outputs, but under certain driving conditions the situation becomes complex and the operator is subjected to a large number of inputs. In such a multidimensional system, the operator must respond at a new rate with a new urgency, making judgments and discarding some of the inputs in favor of more urgent or important ones. In any case, the operator must turn complex displays into discrete items—cars, traffic signals, and the like—in a manner essentially similar to the workings of an electronic computer. In a single-channel system, if the information flow is too fast, the operator merely does badly; but in a multichannel one, overload may cause not simply deterioration, but complete breakdown as well. A frequently experienced need for "gating" of information occurs when several people ask questions of a person at the same time; for example, after a person has delivered a paper. Unless the questions are regarded as discrete and handled separately, communications break down.

The electronics engineer has developed a wonderful piece of equipment in radar, and is constantly improving this information-giving device. The information presented on the scope has raised a number of interesting human problems, of which perhaps the simplest is that of optimal contrast. But a problem of an entirely different order of magnitude and one not in the realm of engineering, either electronic or mechanical, is how much information the operator can receive and use. It is an extremely interesting experience to feed synthetic data into a plan-position indicator scope and observe trained fighter directors. As the load is increased, they begin to exhibit signs of strain. Curiously enough, the men do not become less efficient as the load is increased over a short period of time; but, when the critical point is reached, they break down completely, and cannot go on for a considerable period of time. The analogy of a circuit breaker, when overloaded, is surprisingly apt. Obviously, there are practical everyday implications here in terms of setting operator loads for such workers as control tower operators, train dispatchers, and so forth.

The output of "man-the-machine" is frequently a control operation performed on another machine. In the case of the car, the controls are the steering wheel, brake, clutch, and accelerator. In response to the input signal, the driver operates a control, and the car is displaced in relation to the controlled member of the display. These controls may present problems to the man. The wheel is a positional control, with rapid action; but its rapidity of effect is greatly altered by the speed of the vehicle. Man learns to adjust his response in degrees of turn to the speed of movement of the background members of his visual display. When there is a serious time lag between operation of the control and the movement of the controlled mechanism, as there is in the case of the helm of a boat, the operator must make a judgment to prevent overcontrolling. Basically, man is equipped to work with three types of control: positional, velocity, and acceleration. In steady driving on the open road, the accelerator of a car is a velocity control, with a small time lag. In heavy traffic, where speed is constantly changing, the accelerator becomes an acceleration control. These human factors place limits on the efficiency of any man-machine team, such as tracking control mechanisms.

In general, man receives an input signal, feeds back an output signal, and compares the results with the input. Essentially, he is engaged in measuring the algebraic difference between these inputs and the effects of the outputs on the system. As psychologists, we refer to these differences as errors, misalignments, deviations, or corrections. Actually, they are of precisely the same nature as the self-seeking mechanisms built into many automatic machines.

Timing and Imagination: An astonishing characteristic of man is his awareness of time and timing. A normal man has no trouble in differentiating between "now" and "then," that is, apprehending an event presently transpiring as opposed to one occurring in the past. Even more interesting is the phenomenon of anticipation of an event which is about to happen. An oncoming car may be cut from view momentarily by a passing truck, yet the driver anticipates its likely position when it will come into view and acts accordingly. Of course, an automatic tracker can do this to some extent. But a man driving a car can do much more. For example, in passing a long line of parked cars, he can judge from any one of a dozen cues that a particular car is about to pull out in front of him. A good driver differs from a bad one largely in this ability to anticipate: and no machine has yet been able to imitate him. Anticipation of near events is not to be confused with prediction of events in the future, such as occur in planning the route for a long trip, estimating mileage, selecting routes to be traversed, and notifying friends of expected dates of arrival. At any point on the trip, a situation may arise which will call for a shift in plans to attain the desired objectives at specified points in time and space. Usually, the human machine can solve such a problem, but this nonplanned solution is beyond the capabilities of automatic machines. There is yet another time factor, namely memory of past events, in which the

human machine surpasses the robot. Still another remarkable and unique feature is man's power to recognize patterns, despite wide variations in size and the perspective in which they are seen.

In other words, man is very similar to a machine, but he is also something more. No machine has shown imagination: the ability to conceive of ideas, objects, and situations not yet in existence. These imaginative processes, when combined with a desire for the imagined object, tools with which to work, and a mind which can draw on the accumulated past experiences of itself and others, often turn the "impossible" into realities. This type of action, planning, reasoning, and imagination are far beyond the capabilities of any robot yet conceived. Even if they were within the realm of possibility, the sheer physical mass of the completely integrated structure necessary for the existence of self-controlled, self-maintained, and self-generated robots would make them impossible.

Basically, therefore, we should think of machines, from the simplest to the most complex, as merely extensions of man's own limited senses. They remain under the control of his brain. He can never be under their control because they are his creation: he invents them, sets into them every operation they can perform, and he determines the nature and limits of these operations.

COMPLEXITY OF EQUIPMENT

We are all familiar with many cases in which technological developments have resulted in complex units of equipment which place heavy demands on human operators. Two such typical situations can be drawn from the fields of power and electronics engineering. The first of these is a power control room of a hydroelectric station; the other is a control room of a television station. The one thing which is common to both situations is the complexity of the task confronting the operator in reading and understanding what the equipment is trying to tell him so that he may respond with the correct action or feedback. Both delays and errors can be serious indeed. Often the requirements on the operator for delivering high performance at these complex tasks are increased by demands that he work for prolonged periods of time and, in addition, occasionally under emergency conditions.

The problem of improving the combined efficiency of the man-machine team is not hopeless; on the contrary, a great deal can be done once the limitations and capabilities of the human element are determined for the particular equipment under consideration. The first step involves the application of operation analysis techniques to determine the demands placed both by the equipment and the operational situations upon the operator. Once this is done, the human engineer can often bring to bear data based on experimental findings which will solve part or all of the problems. In other cases, it may be necessary to set up experiments to determine the limits.

One of the values of operations analysis is that it not only breaks down the operations into their components but also that it can set forth the various components of the equipment as distinct units. One of the components of the modern power station is so common that its possibilities as an information display are overlooked. I refer, of course, to the meters. Unfortunately, a power panel almost never consists of a single meter, and even panels composed of a few meters are relatively scarce. The complexity of most modern power panels is such as to tax the visual and intellectual capacities of even an experienced electrician. These visual problems are complicated by such simple things as distance observed, size of scales, different scale units, legibility of characters, contrast of characters to background, the size and type of index pointers, glare, and angle of observation, to mention only a few. Recently we observed a pointer shaped like an ornate fleur-de-lis; and, in another instance, the dial was tilted backwards 30 degrees and also so placed that the observer was 30 degrees to one side, thus cutting down the effective viewing area by 75 per cent. On a single piece of radar equipment an arithmetic, geometric, and logarithmic scale were observed; and, to confuse the operator further, one scale was in tenths, another in thirds, and, believe it or not, another in sevenths.

An Example: Let us now consider a simpler example: the control panel installed on a certain type of Naval vessel. The panel operator was confronted by an array of about 20 separate indicator dials relating to the motor, generator, and battery functions. Any ordered change of speed demanded adjustments by the operator, the adjustments varying in complexity according to the order given. Motion pictures obtained during a series of 65 orders revealed that in only one case were the adjustments by the operator free from defect. A total of 383 defects were observed, an average of almost six each time a speed change was ordered. An analysis was made of the motion pictures to determine the types of errors made and their causes so that the panel could be simplified. It was found that most of the errors could be traced to apparently trivial inconsistencies in meter design. For example:

1. The null position on the meters varied, zero being in the 8 o'clock, 10 o'clock, or 12 o'clock position, depending on the meter. It was recommended that the 8 o'clock position be used as the standard null position, thus ensuring that during normal operations most of the settings would be at the tops of the dials, in the vicinity of 12 o'clock. Thus any deviations from normal can be easily spotted by the operators.

2. In about 20 per cent of the meters, the numbering of scale graduations followed an irregular sequence. For example, in one case the scale was numbered at the following graduations: 1, 2, 3, and 4.5. Such irregularities make accurate quantitative reading of the meter extremely difficult, especially when interpolations are required. The scale graduations on all dials should be numbered in a regular sequence to avoid these difficulties.

3. The three fundamental units with which the operator was concerned were volts, amperes, and revolutions per minute. Examination of the panel indicated that the units employed on the various meters were volts, amperes, kiloamperes, revolutions per minute, and revolutions per minute $\times$ 100. The operators reported that this was a major source of confusion to them, and it was recom-

mended that all meters be designed to read in volts, amperes, and revolutions per minute, even if it meant the printing of a number of zeros on the dial plates.

4. In about 20 per cent of the meters, each scale division represented two units, whereas in the remainder of the cases the scales were based on decimal multiples of 1 or 5. Experiments have shown that scale divisions in multiples of two are responsible for a high percentage of reading errors. Therefore, it was recommended that all scales be designed to read in multiples of 1, 5, 10, or 100. Along the same line, it was found that the number of marked scale divisions between numbered divisions varied; in some cases there were 5, in some 10, and in some 15. Experimental evidence indicates that most accurate readings are obtained with 10 marked divisions between numbered divisions; therefore, it was recommended that all meters be so designed.

Equally as important as the effective design of indicator dials for optimum human performance are the design and arrangement of control knobs and consideration of normal control-display relationship. On an electric range produced by a well-known manufacturer, the degree of heat on each burner is controlled by a row of push buttons. A survey performed on a sample of housewives demonstrated that two major sources of confusion existed:

1. The push buttons were arranged from left to right in descending degrees of heat rather than in the normally expected ascending sequence.
2. The labels, designed to describe the degree of heat at each step, were extremely ambiguous and followed no logical system.

It is not known how many dinners were spoiled because of the poorly designed controls, but two principles of human engineering are illustrated:

1. Left-to-right sequence or clockwise rotation of controls should be used for increasing functions.
2. Control knobs should be clearly and unambiguously labeled.

A radio console was studied recently on which clockwise rotation of the tuning knob resulted in counterclockwise rotation of the station dials. This type of control-display relationship increases the chance of the operator making what is commonly termed a reversal error, that is, turning the control in the wrong direction. Admittedly, this is not serious in the case of a commercial radio set, but inconsistent control-display relationships frequently are found on equipment which must be operated quickly and accurately in the interests of safety.

INSPECTION

Almost as important as the designing of equipment and the production of finished goods is the job of inspection. The quality of finished products, of course, is determined by the raw materials, the specific processing, and the workmanship; but, since both men and machines vary in their performance, the manufacturer must inspect the final product in order to grade it and represent it fairly to his customers. Very often final inspection of the product is only one of many in a series. Even now engineers are engaged in developing new and better electronic devices which promise to do better jobs than current devices. Certainly, we may look forward to the time when the human factor is at a minimum in inspection. Nevertheless, the human factor still has to be considered in developing such gadgets.

One of the most recent and ingenious of such devices, the Limitron, made by the Arma Corporation, is able to identify acceptable parts and oversize and undersize rejects. A light system flashes green for acceptable parts and red and yellow for rejects, informing the operator of the trend of production. This device places a very simple demand on the operator, but there are individuals who cannot use it—for example, persons who are red-green blind.

Many electronic inspection devices require an operator to interpret a dial or other form of display. In developing such instruments, it should be remembered that the operator's task will be much easier if a "go-no-go" type of display is employed rather than one requiring the operator to read a scale to some such limit as 2.75. Further, when several points are to be inspected and the results indicated on dials, one master dial should be provided which would indicate that all points are acceptable.

Now let us consider the inspection of two products which are very different but which had the same basic cause underlying inspection failure. A company manufacturing tapered roller bearings was experiencing difficulty in retaining skilled female inspectors. It was recognized that the job was difficult and fatiguing since the inspectors had to examine the side and bottom surfaces of the moving rolls for seven different surface defects. These rolls were presented to the inspectors by a machine at a rate of 49 per minute. Examination of the workplace revealed that certain changes might improve the quality of inspection and make the task easier for the operators. An experimental study was designed in which lighting, work period, classification of defects, speed of presenting rollers, and contrast of the machine with the rollers were varied. Special coded lots containing approximately 10-per cent defective rollers were inspected. The optimal conditions of illumination, length of work period, classification, speed, and conditions of contrast were identified. With constant usage, the parts of the machine which delivered the rollers became bright, shiny, metallic surfaces which were impossible to differentiate from the rollers. Since the rollers were always moving when they were inspected, it was very difficult to differentiate between roller and background. This situation was corrected by coating the machine with a deep low-reflecting black. Inspection improved markedly under the conditions of higher contrast.

In a pharmaceutical company the number of pills per bottle was checked by an inspector who poured the neutral colored pills out on to a small wooden paddle containing a number of holes. When all the holes were filled, the bottle contained the correct number of pills. Unfortunately the contrast level between the pills and the holes in the paddle was so low that often the inspector was

unable to determine whether or not the hole contained a pill. This situation was corrected by coloring the bottom of the hole orange, thus making the indentations which lacked pills easily distinguishable from those which contained pills.

These changes were accompanied with the expected rise in efficiency. These examples indicate that common environmental conditions influence the operator's performance even though the products inspected differ markedly.

PROBLEM OF LEARNING

Another aspect of the man-machine relationship is the problem of training or learning. One of my associates, while visiting neighbors, noticed that the picture on their television set was not clear. He fiddled with the controls, and after a while improved the picture markedly. In discussing the tuning of the set, he discovered that the people who owned it had never really learned how to tune it. Since he had had some trouble in tuning the set himself, he examined it more closely. This is what he found:

1. The controls and their legends were on a panel perpendicular to and below the screen.
2. In learning to adjust the picture, the viewer must change from a position where he can see the controls and legends to one where he can see the screen.
3. Even after learning to tune the set, the viewer must simultaneously reach forward to grasp the controls and squat to see the picture.
4. Learning difficulty and operating discomfort could easily be reduced by placing the controls on vertical panels alongside the screen, as manufacturers of various television sets have done.

This example illustrates rather clearly the direct relationship between the design aspects of a product and difficulty in training the user or operator. Now, if there is learning difficulty on a mass-consumption product like a television set, think for a moment about the training problems that are involved on more complicated equipment. Finally, consider the effect of this on customer satisfaction and future sales.

For example, the advent of new, high-speed bombardment aircraft, where design characteristics seriously limit the space available for personnel and thus require the consolidation of the duties of navigator, radar operator, and bombardier into a single job performed by one man, has raised certain problems regarding the design of equipment to be so used. One such problem studied was: what type of radar bombing presentation makes for the most rapid and accurate identification of targets presented on the plan-position indicator navigation scope? Using learning curve data, it was found that 13.5 per cent more targets were correctly recognized with a polar grid presentation than with a Cartesian grid. In another phase of the same study, the difficulty of learning to recognize targets when the sector scope was heading stabilized was compared with learning difficulty under azimuth stabilization. 30.8 per cent more targets were correctly recognized under heading stabilization than they were under azimuth stabilization.

Sensory-Motor Problems: To psychologists, these are known as sensory-motor problems. They require that the operator continually perceive and discriminate between all of the stimuli which are presented to him and then differentiate between all of the possible responses which he can make in order to select the proper one. There are recent studies which show just how serious these problems can be for complex situations. It was found that, as the rate at which critical display changes occur increases, errors of response increase logarithmically. Also, as the load is increased by increasing the number of different stimuli which comprise the changing display, response errors increase markedly. Finally, errors in timing of responses were found to double as the load doubles. Other studies of this kind have indicated that reaction times increase sharply as the stimuli to be discriminated become more complex.

These examples help to illustrate the relationship between "surface" or "skin" aspects of design and the human operator. In proportion as the engineer considers the human aspects of the equipment he designs, he is actually helping to solve personnel problems, which, as you probably know, are among the most difficult managements must face. Better human engineering means less difficulty in selecting and training personnel, and, in some instances, a smaller number of people necessary to do the job. This point is particularly important during periods of full employment, such as we are now experiencing.

MAINTENANCE

Another problem encountered in our work with electric equipment is concerned with maintenance. Let me give you a quick example: One well-known household electric clothes dryer has its lint box at floor level. Proper lint removal requires lying prone on the floor and having a longer than average reach. Removing lint is particularly uncomfortable and distasteful when floors are wet, damp, crowded, and when housewives are pregnant. A competitor's dryer has its lint box within easy reach from a standing position.

Here are several other examples that we have encountered on more complex equipment:

1. Test meters located so that it is practically impossible to see them from the point at which the adjustments are to be made.
2. Highly inaccessible adjustment controls that have to be used so frequently that they would be better located on an operating panel.
3. A required precision of dial setting that is beyond the operator's capacity to perform.
4. Constructing equipment so that it requires special maintenance tools when, for the most part, it would have been just as easy to make it so that ordinary tools could be used.
5. A real need for trouble lights on indicator panels.
6. Trouble shooting charts and procedures which are inadequate if available at all.

All of these things are significant. Together they tend to make maintenance difficult, distasteful, expensive, and, in many instances, unreliable. In addition, they tend to raise personnel requirements in terms of specialized knowledge and skills, training time, and so forth. One of the most serious problems currently faced by the military is, of course, the shortage of well-trained electronics maintenance personnel.

CONCLUSIONS

These are typical problems which human engineering is called upon to solve. As equipment becomes more complex, the human engineer will play a role directly parallel to that of the design engineer. It will be his job to see that the task which must be performed is kept within human bounds by presenting information so that it can be understood rapidly and accurately and by facilitating proper responses. In addition, he will have to keep in mind such factors as motivation and fatigue to insure a sustained high level of performance. Engineers have found that when they have the support of the human engineer or experimental psychologist in the early design and mock-up stages of the development of a new instrument they not only come up with better equipment from the operator's standpoint but they also forestall many costly changes which have to be made after field trials. The human engineer is not concerned with the design in terms of function, but he can be of real assistance to the electrical and electronics designer in terms of the connecting links between the human and mechanical parts of the man-machine team. Occasionally, apparent conflicts arise between the demands of the man and the machine; but it has been my experience that these can be resolved satisfactorily.

The limits on man's ingenuity with equipment apparently are set by man himself, but we will fall far short in the development of new equipment unless we know and apply the limits of the human member of the team.

The Design of Power-Line Capacitors for Series Installation

B. O. N. HANSSON
MEMBER AIEE

The high short-time stresses and discharges to which a series capacitor is exposed demand special design of the capacitor unit. The elements of such a design are reviewed, and two Swedish installations, one now in operation and the other under construction, are described.

A capacitor for series installation in power lines is fundamentally an extremely simple apparatus constructed of only three components; the electrodes, the paper, and the impregnating liquid.

It is possible to adapt the quality of the components and the design to obtain a capacitor which is exceptionally resistant to the high short-time stresses and discharges to which a series capacitor is exposed. Some unusual measures taken in the design of the Alfta capacitors will be listed here. They will be illustrated by a life curve which comprises not only the a-c strength versus time, but in addition curves or points for d-c and impulse strength. Such a "complete life curve" is shown in Figure 1.

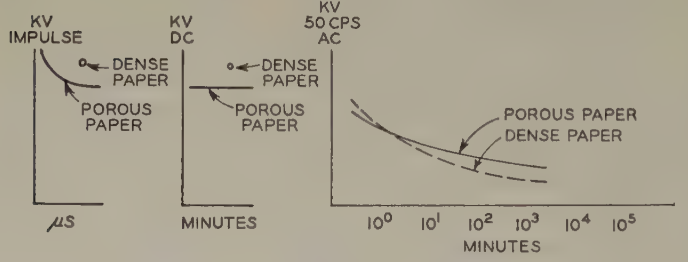

Figure 1. Effect of the denseness of the paper on dielectric strength

Knowledge of the left part of this curve (impulse strength versus time) is still incomplete. This field has been explored only during the last decade, while the right part, the long-time a-c strength, is well known. That part has been the scope of much research ever since paper cables were introduced more than 50 years ago. The d-c part is of special interest for d-c cables and d-c capacitors and for the d-c testing of capacitors and cables.

The part of the a-c curve which extends towards very short times is still fairly unknown. It is, however, that part which is most interesting for the design of series capacitors.

Essential text of paper 51-332, "The Design of Capacitor Units for Series Connection," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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The right part of the complete curve in Figure 1 (long-time a-c breakdown) entirely depends on the dielectric losses and the ability of the design to dissipate those losses. Long-time breakdowns are thermal breakdowns and show a burnt structure.

A-c breakdowns which occur after a shorter time may be thermal breakdowns, but during this short time the

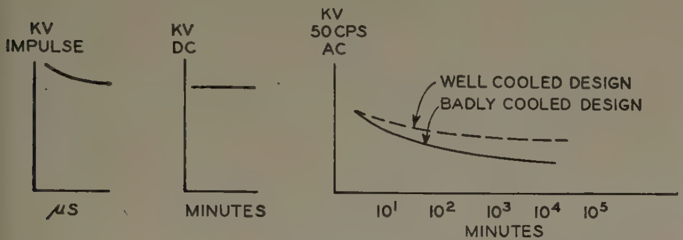


Figure 2. How the cooling affects the dielectric strength

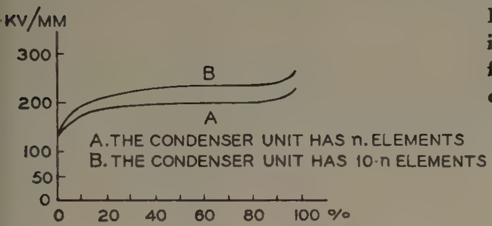


Figure 3. How sorting out tests and fuses improve the dielectric strength of a capacitor

heat is not dissipated. It is absorbed by the heat capacity of the dielectric and the armatures.

VARIATIONS IN COMPONENTS

A DENSE PAPER represents a more difficult obstacle for the impulse and d-c breakdowns; but a dense paper means more cellulose content in the insulation and therefore higher losses and reduced strength against such a-c stresses as cause thermal breakdown. Increased paper density tilts the complete life curve, increasing strength for impulse, direct current, and short-time alternating current but lowering the strength for long-time alternating current. Dense paper should be used in series capacitors if the design can afford the increased temperature at rated voltage.

The viscosity of the oil seems to have a similar influence on the dielectric strength as the paper density. It is difficult to prove this, as oils with different viscosities are also different chemically and in other ways.

The fact is that a more viscous oil will give higher impulse and d-c strength, but it may also give higher losses and therefore impart a lower long-time a-c strength to the impregnated paper than a thin oil. In the Alfta capacitor an oil thicker than transformer oil was used.

A relatively small increase in impulse and d-c strength is obtained because of the increased viscosity of the oil at very low temperatures, but the influence of the thermal design of the capacitor on its dielectric strength is more important. Figure 2 shows this effect.

The heat capacity determines the short-time a-c breakdown and the heat dissipation the long-time breakdown. A design which gives better cooling and lower temperature in the insulation lifts the long-time a-c parts of the life curve upwards. This applies to the "foil-cooled" design as used in the Alfta capacitor to be described.

An effective way to improve dielectric strength is to test the material until breakdown occurs and then disconnect or repair the faulty pieces.

This method is probably now used by all capacitor makers. The capacitors are divided up into many small sections and those which break down for the test voltage are disconnected.

In Figure 3 the strengths of the different sections of such a capacitor are arranged consecutively. If 5 per cent of the elements are punctured and disconnected, the total dielectric strength of the capacitor is increased from 130 to 150 kilovolts per millimeter, that is, by 15 per cent. If the number of elements were increased tenfold (as in curve B, Figure 4) then an elimination test which punctures 5 per cent of the windings would increase the strength from 130 kilovolts per millimeter to 170, that is, by 30 per cent.

For this sorting out of the weak parts of the insulation only direct current may be used, because alternating current may cause thermal deterioration not only of the punctured windings but also of those which are nearly as weak as the punctured ones. This method improves only the impulse, the d-c, and perhaps the short-time a-c strength of the capacitor, but no guarantee is given that the long-time a-c strength is also improved because that strength is highly influenced by spots or sections which have high losses. Further attention will be given to these facts.

If each section is separately fused it will be disconnected, regardless of the time it takes, if it does not hold for all the separate or combined overvoltages the capacitor may meet during its life. If thus each element is tested with

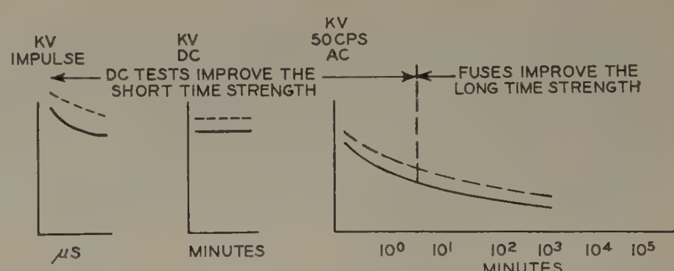


Figure 4. Strength of the different elements in a capacitor unit arranged consecutively

direct current and further has its own fuse, then the impulse, the d-c, and the a-c strength will be improved. See Figure 4.

OIL PRESSURE

THE OPINION may now be commonly accepted that an increased oil pressure improves the a-c dielectric strength of the impregnated paper but that it has no influence on the d-c and the impulse strength. See Figure 5.

Much research on this question, not only in connection

with pressure capacitors but also with the 380-kv paper-insulated cable, recently installed at Harspranget in northern Sweden, has revealed that this statement is not quite true. As at the same time the nature of the different

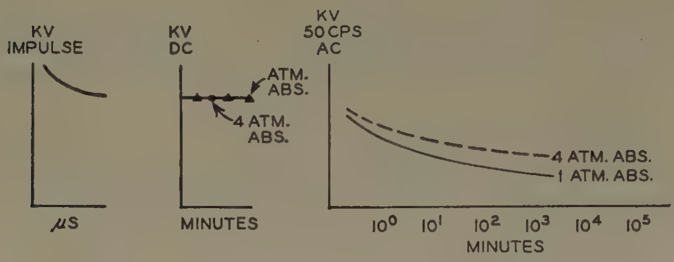


Figure 5. Effect of oil pressure on dielectric strength

breakdowns has been made clear, it will be of interest to deal with this question at some length.

Capacitor insulation consists of interleaved layers of paper and oil films. (Actually the paper itself has a very complicated structure—fibers, fibriles, mizelles, and the molecules—but this can be disregarded for the present.)

The dielectric constant of cellulose is 5.6 and that of oil is 2.3. With alternating current the main stress therefore would occur over the oil component.

With direct current the stresses on dielectrics connected in series distribute themselves proportionally to the insulation resistances. For cellulose and oil these resistances are such that the cellulose component would take the highest stress with direct current.

This working hypothesis has proved of great value when judging the stresses in a series capacitor at the unusual load it is exposed to in service and during tests. It might be of interest to review some recent indirect evidence that the hypothesis is true.

A glance at Figure 6 will show better than many words what the writer wants to express. As regards impulse and direct current the opinion formerly was that the strength of impregnated paper was independent of the pressure, in spite of the fact that the strength of the oil is highly dependent on pressure. Towards direct current and impulse voltage, impregnated paper dielectric behaved like a solid.

Would it not be possible, by using an oil or other liquid of poor dielectric strength or with very good insulation resistance, to cause the breakdown to start in the impregnant and thus make the d-c and impulse breakdowns dependent on pressure? If an impregnating liquid could be found which at some temperatures had higher and at other temperatures lower insulation resistance than cellulose, it ought to be possible to study the nature of the breakdown in detail. Up to now this has not been successful but by decreasing the dielectric strength of the oil by means of a pressure lower than the atmospheric it has been possible to decrease the strength of the oil so that the strength of the impregnated paper becomes pressure-dependent also at direct current and impulse.

For several decades gas ionization in voids has been recognized as the cause for the deterioration and breakdown of solid cables. For some time it was believed that oil-filled cables and capacitors properly impregnated with thin oil were free from such ionization. Improved technique, however, developed the ionization bridge with which increased losses could be traced at stresses below breakdown. When once such a bridge was out of order a new way was invented to find the ionization point. It also was suspected that the bridge might not be able to trace loss increases in an infinitely small spot when the losses were measured on the whole bulk of the capacitor's insulation.

A capacitor was tested step-by-step with increasing voltage during a period of 2 minutes. After each step at high test voltage the capacitor was loaded for 5 hours with the rated voltage and then the losses were measured. The test voltage at which the losses started to increase was named the ionization point.

From Figure 7 it can be seen that high oil pressure and thin insulation should be used to give a high ionization point.

It remains to be seen if the ionization point thus obtained is a true ionization point or if it just indicates the stress at which decomposition of the insulation has started. In

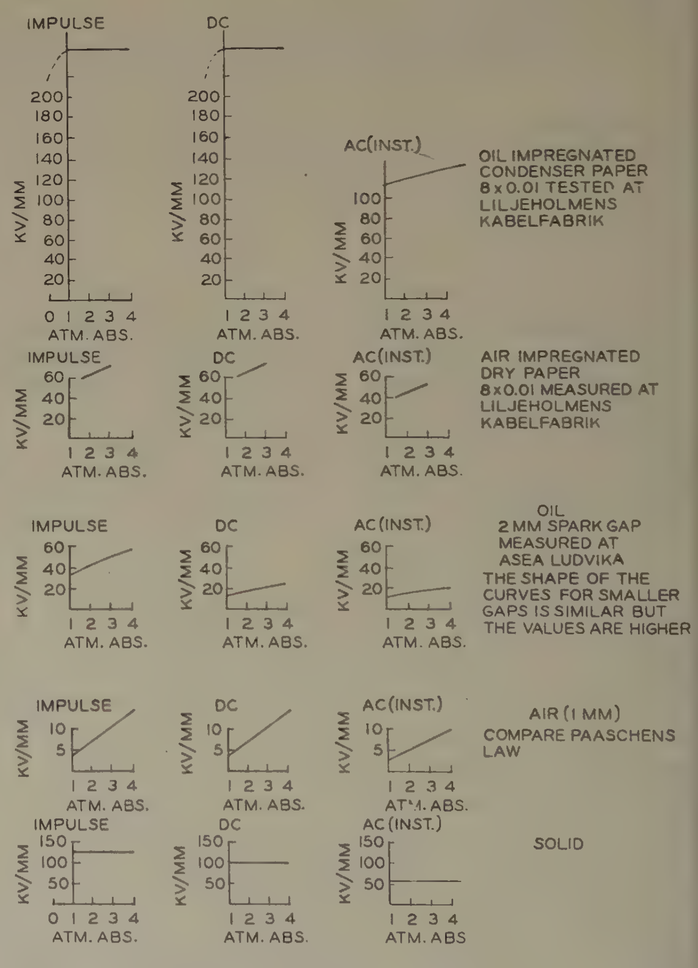


Figure 6. Charts of the short-time dielectric strength versus pressure illustrating the nature of breakdown in different materials. For oil-impregnated paper as used in cables (with thicker insulation and oil pockets between papers) the impulse and d-c strength appears to be more pressure-dependent than capacitor insulation

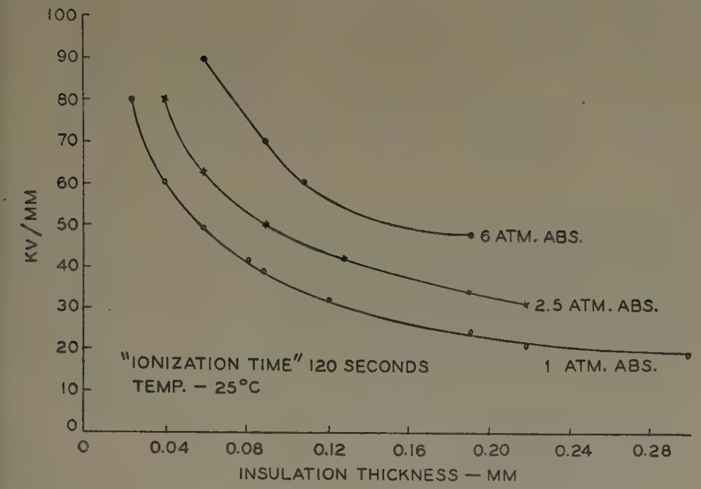
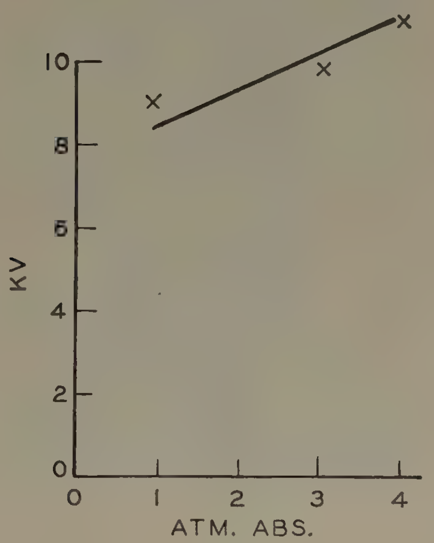


Figure 7. Ionization stress at varying insulation thickness and oil pressure

Figure 8. Discharge strength of capacitors



the latter case the ionization point should be time-dependent. It might also be a combination of both. This test method is a very valuable tool for tracing a "decomposition curve" below the life curve, above which the capacitor never should be used or tested.

DISCHARGE STRENGTH

Experience with the Swedish discharge test for coupling capacitors and with capacitors for surge generators and for discharge welding has been quite discouraging. Capacitors are rather sensitive to discharge. Similar experience has been gained recently from the testing of 220-kv cables with direct current (as a substitute for impulse testing). Such a 220-kv cable would withstand easily a 1,050-kv d-c test but if, due to ionization of the air and poor grading of the terminal porcelain, the porcelain flashed over, the cable would invariably break down under this stress.

Here again the working hypothesis referred to previously is useful. When the d-c voltage is on, the main stress is over the paper, but when the a-c discharge starts, the main stress shifts over to the oil which simply breaks down. The stress is too high. If this theory is right an increased oil pressure should raise the "discharge strength" of a capacitor. Ample proof is given by the test results plotted in Figure 8.

The fundamental theories behind the design of the series capacitor for Alfta now have been recapitulated and in the following a brief description of the construction of the units will be given. See Figure 9.

The capacitor units are "foil-cooled." One of the two aluminium foils which protrudes out of the winding is pressed tightly against the wall of the capacitor tank. On the outside this wall has cooling fins. Direct metallical conduction of the losses from the interior of the capacitor windings to the surrounding atmosphere thus is established. The other foil is connected to a lead-through insulator soldered to the tank.

The wall opposite the cooling wall is a steel diaphragm, capable of exerting an overpressure of up to 3 to 4 atmospheres on the oil and capable of taking care of the heat expansion of the oil.

In the Alfta capacitor such a unit was divided into 7 windings, each one equipped with its own fuse. No series connection was allowed inside the tank. Many units in the final arrangement were connected in parallel.

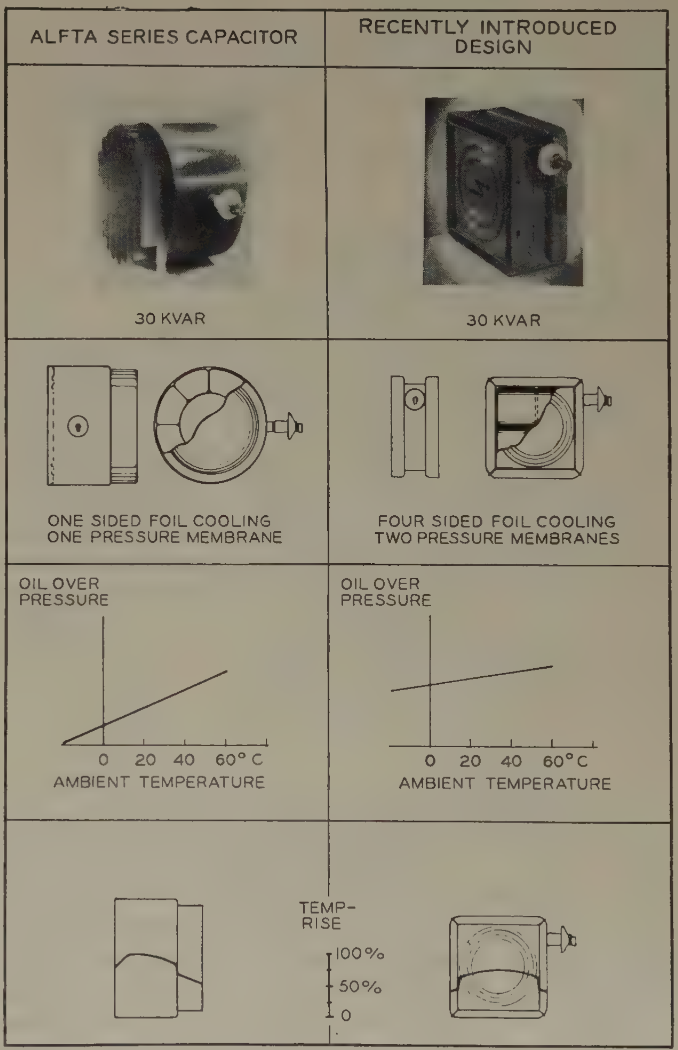


Figure 9. Comparison between the design of Alfta units and new capacitor units

These groups of many parallel-connected units then were connected in series with similar groups. If a breakdown should occur in one small winding, the short-circuit current would be limited by the series-connected capacity. The capacity in parallel contains a suitable quantity of energy to blow the fuse when it is discharged through the faulty winding.

In the factory all units were tested with direct current at 6 times the rated voltage E, and a few units failed. Among all the 600 units at Alfta there must be one unit that just escaped failure and has no safety margin for a d-c voltage of $6E$. A number of units were tested successfully with three consecutive discharges from $5E$ (followed by the rated voltage and loss measurements) but it is not known whether the remaining units would have escaped safely from that test. All units were not tested that way as the high frequency discharge might impair the useful life of the capacitor.

At the final tests after construction the total bank was charged with direct current and then discharged through the spark gap that was set at $4.2E$.

If any unexpected weakness or overvoltage should show up during service, the internal fuses would clear these faults unnoticeably. One year after installation the capacitance of each unit in the installation was checked. All units were found to be intact.

Recently new tests were carried out to obtain the a-c life curve for the breakdown strength of full size units for very short time.

The result is in the shape of a life curve given in Figure

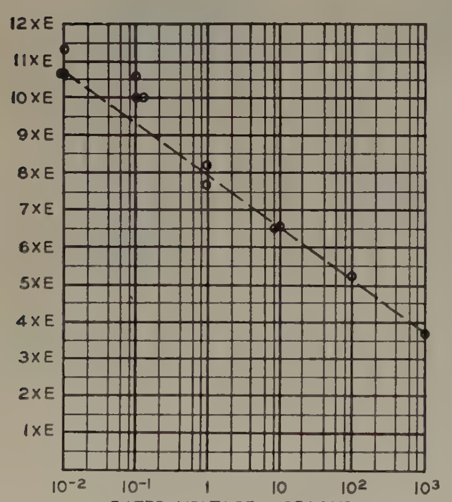


Figure 10. Fifty-cycle strength of capacitor units for Alfta at very short time. Each circle represents one unit. The voltage was increased step-by-step when the capacitor was given voltage shots of the duration indicated on the diagram

10. In each test three capacitor units were tested. Each unit was given many shots with gradually increased voltage before the breakdown voltage was found.

In future tests each shot will be followed by 24 hours of rated voltage and by a check of the dielectric losses to find the voltage (the ionization point) at which destruction of the insulation starts.

For the design of future series capacitors confidence and knowledge has been gained from severe tests and service records and the design of series capacitors most probably need not be limited by stipulations that the units should be suitable as shunt capacitors in case of failure. There are great possibilities of producing a series capacitor that is specially suited for this service when we fully know the stresses to which the capacitor may be exposed during its

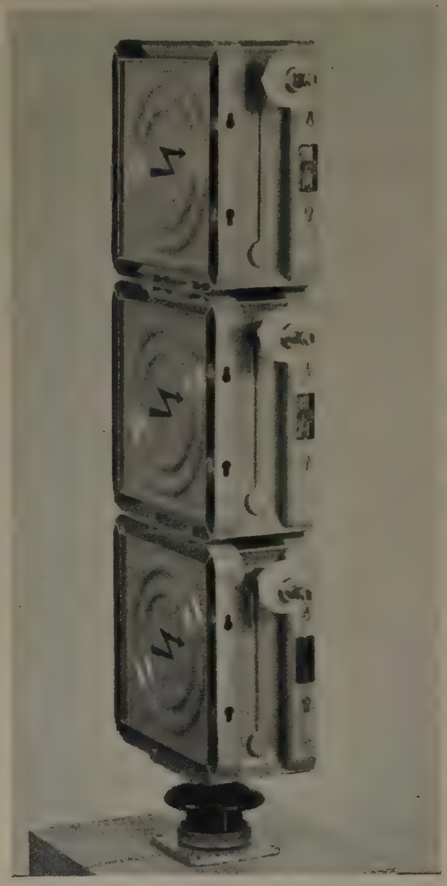


Figure 11. A 75-kva 3,000-volt capacitor. The three units are connected together by nuts and bolts and do not require racks for connecting into banks

life. Perfect service for $1^1/_2$ years has proved the reliability of the design used for the Alfta capacitor.

The Alfta design has been improved considerably in a new 50,000-kva series capacitor now in production. See Figure 8. A more compact interior design of this unit gives reduced oil volume and thus less oil expansion. This, coupled with the use of two steel membranes, makes possible the use of a still higher oil pressure which is less dependent on the temperature of the unit. Even at the lowest possible ambient temperatures an overpressure of about one atmosphere is insured.

In these units not only one but four "cooling" walls are in metallic contact with the aluminum foils protruding out of the windings.

This 4-sided foil cooling would be superfluous for a series capacitor, but also in this case the bank had to be arranged in such a way that it might be used as shunt capacitor. Even series capacitors for long periods of time may run overloaded and in that case effective cooling must be provided for.

A special feature of the new unit are the cooling flanges which are arranged as 4-sided mounting flanges. Units may be connected to huge banks without racks, merely by nuts and bolts, as shown in Figure 11, thus simplifying the installation procedure considerably.

Acoustic Models of Transformer Installations

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THE CONTINUING GROWTH of system generating and distributing capacity has caused many power companies to consider carefully the noise level of new transformer installations, or possible increases in the noise level at established stations and substations.

Of existing methods for noise reduction, the use of barriers or roofless enclosures often offers the best compromise between effectiveness and cost. However, the prediction of barrier effectiveness by mathematical analysis of the sound field in most urban locations is of such complexity that little confidence can be placed in the quantitative results. To overcome this difficulty, a technique for testing acoustic models has been developed. While it does not establish absolute ambient sound levels as affected by the added transformer noise, it does predict relative levels over areas of interest and supplies useful information which permits design of the barriers. An area of high concentration of sound energy, caused by reflections from buildings and topographical features, can be determined in advance by model technique with the resulting possibility that slight changes in the installation can place these concentrations where the chance of complaints is small.

The acoustical principle of similarity states that for any acoustical system involving diffraction and reflection phenomena it is possible to construct a new system on a different scale which will exhibit similar performance, providing the wavelength of the sound is altered in the same ratio as the linear dimensions of the new system. This principle justifies the use of a model to predict the performance of an actual system. In place of transformers, comparatively simple sound sources are used, and in place of the complex array of buswork and other station equipment, only structures whose dimensions are large compared to the wavelength of the sound under consideration are included. Since both structural and topographical features consist mainly of acoustically hard (for example, highly reflective) materials, wood is used for most of the model structures.

The model transformers consist of small loudspeakers mounted inside a rectangular wooden framework upon which a paper skin is cemented and shrunk. This simulates the complex vibrational pattern which exists in the tank walls of an actual transformer. Because of wave interference, the sound field from any surface undergoing a complex mode of vibration, such as a transformer tank, exhibits a pattern with large abrupt changes in sound pressure as a function of location. To average out these variations so that interpretable data may be obtained, a frequency-modulated sound is employed in model testing.

Digest of paper 51-56, "Acoustic Models of Transformer Installations," recommended by the AIEE Committee on Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. Published in AIEE *Transactions*, volume 70, part I, 1951, pages 333–38.

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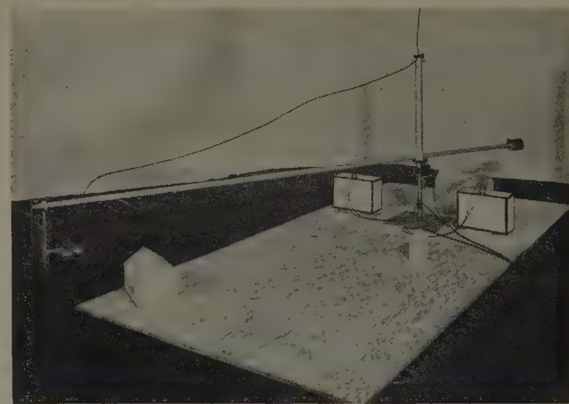

Figure 1. Typical acoustic model of transformer installation, showing transformers, buildings, and microphone transport mechanism

The sound from the transformer models is picked up by the microphone of a sound-level meter. The microphone is transported around the model at a fixed radius and height by a motor-driven rotating boom. A typical test setup is shown in Figure 1. The output of the sound level meter is fed to a high-speed recorder, which plots a curve of sound level versus angular position of the microphone.

The economy with which a great many wall designs may be tested on a model, as compared with the construction and test of even one design on the prototype, is apparent. The model shown is simple, for the purpose of illustration. Real situations are usually of greater physical and acoustical complexity.

Agreement between prediction and practice, together with the fact that acoustic models are sound in theory and that all phenomena observed so far are qualitatively consistent with theory, establishes confidence in the results of model tests. The technique is fully applicable to situations which involve the noise of other machinery. All instrumentation is of comparative simplicity and availability; similar measurements can be made successfully by many power companies with their sound specialists and existing facilities.

Conclusions drawn from two years' experience are:

1. The prediction of the relative average values of sound pressure in the area around a transformer installation can be made effectively and rapidly by the use of an acoustic model.

2. The evaluation of many different designs for sound-reducing barriers is made economically feasible by tests on a model of the installation in question.

3. The cost of model testing is usually a small fraction of the investment savings obtainable by choosing the best sound control or corrective measures.

Electric Power for Jet-Engine Research

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Jet-engine and rocket research facilities put some severe and unusual demands on the electric power supply system. The distribution system of the NACA's Lewis Flight Propulsion Laboratory, where several large wind tunnels and other heavy equipment must be supplied, is described in this article.

RESEARCH ON THE FUNDAMENTAL problems associated with aircraft propulsion requires many unusual applications of electric equipment and large blocks of power to operate this equipment. This phase of research is the assignment of the Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics (NACA) located in Cleveland, Ohio. Construction of this laboratory started early in 1941, at which time emphasis was on the reciprocating engine as a means of aircraft propulsion. At present, research is being conducted on four basic types of power plants—turbojet engines, turbine-propeller engines, ram-jet engines, and rockets. The shift in emphasis from reciprocating engines to jet engines and rockets, the rapid increase in size of aircraft engines, and the unique conditions under which most basic research is conducted have all contributed toward a number of unusual and interesting electrical problems.

The Lewis laboratory has, in addition to the several large tunnels similar to those operated at the other two NACA laboratories at Langley Field, Va., and Moffett Field, Calif., numerous smaller test stands or cells for research on the component parts of the propulsion system, such as compressors, turbines, combustors, blades, fuel systems, and controls. This type of research lends itself to the multicellular type of facility where a common air or other service system can be used to supply simultaneously a number of cells or test stands.

DISTRIBUTION SYSTEM SELECTION

THE LEWIS LABORATORY at present is supplied by two 132-kv power lines (Figure 1) with a total capacity of approximately 150,000 kva. These two lines are tapped directly to the Cleveland Electric Illuminating Company's main ring bus and terminate in a government-owned substation, known as substation A, located at the south edge of the property. At substation A, transformation is provided from 132 kv to 33 kv, and the lines are parallel-connected on the secondary side. From substation B, underground cables radiate to five banks of transformers known as substations C, D, E, F, and H, which supply power to the northerly half of the plot. Transformers in these substations are rated at from 3,750 kva to 10,000 kva normal rating. All power and telephone lines within the plot, except for temporary installations, are carried in underground cables.

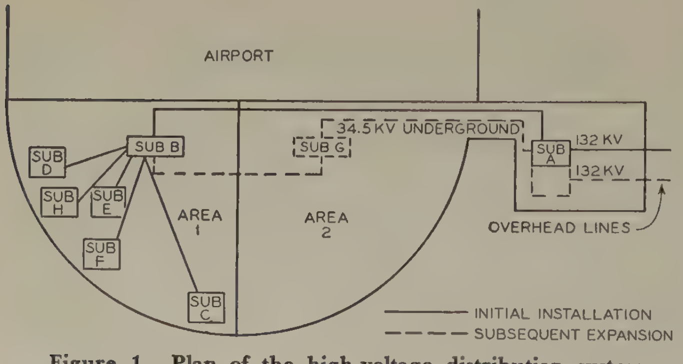

Figure 1. Plan of the high-voltage distribution system

In selecting the original distribution system, five major factors were considered. These factors are discussed individually in the following paragraphs.

Maximum Future Power Requirements. In June of 1941 the power requirements for the time when the initial construction program of the Lewis laboratory would be completed were estimated to be 4,200 kw firm demand, 40,500 kw off-peak demand, and 941,000 kilowatt-hours energy consumption per month. Five years later the actual power requirements had exceeded 27,000 kw firm demand, 35,000 kw off-peak demand, and 4,000,000 kilowatt-hours energy consumption. Nine years after the 1941 estimate, the actual power requirements had exceeded 90,000 kw on-peak demand, 101,000 kw off-peak demand, and 11,800,000 kilowatt-hours energy consumption. Figure 2 shows how rapid this increase in power requirements has been.

As reciprocating engines began to reach limitations in size, the shift from reciprocating engines to jet engines and rockets, commencing in the fiscal year 1943, opened up possibilities of much greater horsepower per unit. The increase in power requirements has coincided with the growth of the aviation industry and in particular with the rapid development of power plants for aircraft. A measure of this growth is the size of tunnels for testing aircraft and aircraft engines. The rate of increase in tunnel horse-

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power is illustrated by Figure 3. No one knows what form this curve will take in the future.

Proximity to the Cleveland Airport. Since the land occupied by the Lewis laboratory is adjacent to the Cleveland Airport, as shown in Figure 1, it became necessary to

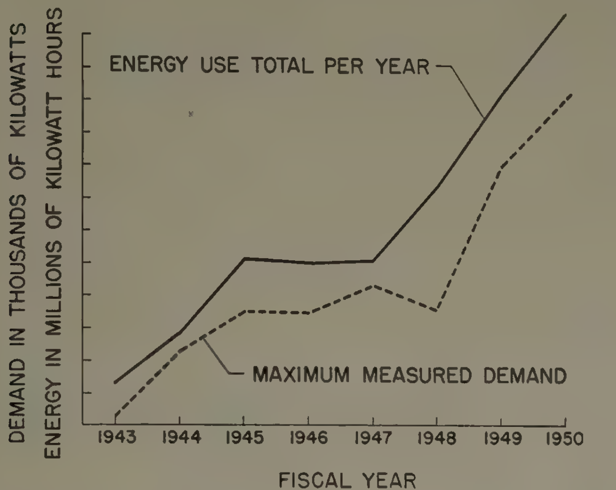

Figure 2. Power demand and energy use of the Lewis laboratory

distribute power underground. Power is supplied by the Cleveland Electric Illuminating Company at 132,000 volts, by overhead transmission lines. In 1941, underground transmission at that voltage was considered to be in the experimental stage. After careful analysis, 34,500 volts was selected as the most practical voltage for underground distribution.

Maximum Short-Circuit Capacity. In 1942, computations of short-circuit capacity were made which were considered to be conservative; however, unexpected increases in load and the greater suitability of synchronous equipment for many of the loads resulted in much larger values of potential short circuit. A tabulation of selected results is shown in Table I. As a result of the 1944 study, the 500,000-kva circuit breakers have been rebuilt to withstand 1,000,000 kva at substation B and 1,500,000 kva at substation A. Steps are being taken to replace the 50,000-kva circuit breakers with 100,000-kva or greater circuit breakers if space permits.

Future Physical Expansion. To provide for future expansion, the incoming substation (substation A) was located in a manner to permit expansion in either direction, as shown in Figure 1. Since the initial construction of research facilities was confined to one-half the plot, it permitted the location of a distribution substation (substation B) in that half with provision for duplication of this facility in the second half of the plot at a later date. This has since been accomplished with the construction of the 8- by 6-foot supersonic wind tunnel, which is supplied by substation G. The three substations then were looped to promote continuity of service.

Maximum Capacity and Flexibility for Minimum Cost. The initial 132-kv line which supplied the laboratory had an estimated capacity of 70,000 kva. The main transformers at the incoming substation were purchased with an air-blown capacity to match the capacity of the line, thus providing additional expansion without purchasing more transformer capacity. In establishing the location of the main incoming substation, provision was made for the expansion of the substation in either direction with space for an additional incoming line of equal capacity. Space for expansion was provided at all major substations and spare ducts were provided in most of the duct lines.

One of the problems connected with the distribution system was that encountered as a result of migration of the compound in solid-type cables originally installed. The demand of the laboratory, by reason of certain large major facilities that do not run continuously, has always varied from a few kilowatts to a maximum value. These extremes frequently have been reached each working day. This

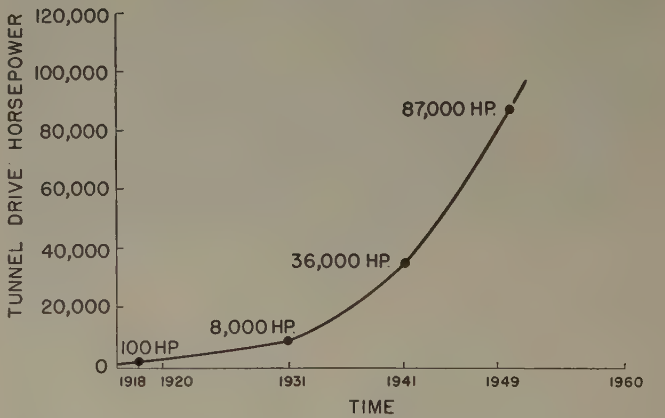

Figure 3. Horsepower requirements of the wind tunnel drive

type of load has resulted in an apparent migration of compound in the solid-type cables with resultant failure. In view of this development, cables added later were purchased as low-pressure gas-filled cables. These cables have solved this problem satisfactorily.

Table I. Computed Short-Circuit Capacity Values

	Short-Circuit Values, Kva			
Location	1942 Computation	Circuit Breaker Selected	1944 Computation	1949 Computation
Substation A 132-kv bus	750,000	1,500,000	1,054,000	1,156,000
Substation A 34.5-kv bus	352,000	500,000	574,000	1,198,000
Substation B 34.5-kv bus	347,000	500,000	570,000	901,000
Engine Research 2.4-kv bus	43,500	50,000	63,200	57,500

WIND TUNNELS AND TANKS

Among the larger tunnels at the Lewis laboratory are the altitude wind tunnel, the 8- by 6-foot supersonic wind tunnel, and the icing research tunnel. The altitude wind tunnel and the icing research tunnel are powered by the Clymer or modified Kraemer type of drive. The 8-

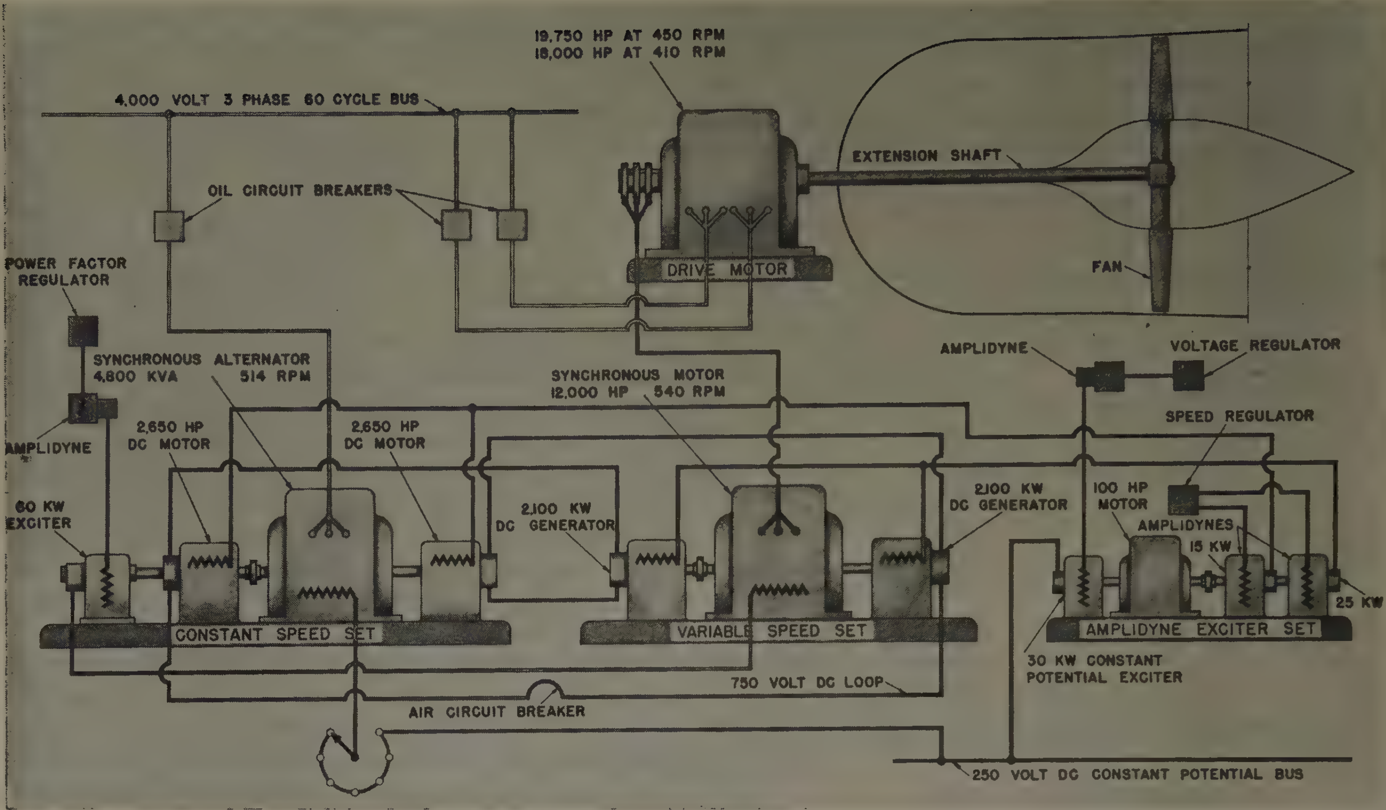

Figure 4. Electric drive system of the altitude wind tunnel. It consists essentially of a constant-speed motor-generator set and a variable-speed motor-generator set controlled by amplidynes

by 6-foot supersonic wind tunnel has the liquid rheostat control type of drive.

Altitude Wind Tunnel. The altitude wind tunnel provides means of performing research on aircraft power plants in an air stream flowing up to 500 miles per hour and under controlled conditions of temperature and density existing from about sea level up to 50,000-foot elevation. The flow of air is maintained by means of a 32-foot-diameter 12-blade propeller driven by a wound-rotor motor rated at 19,750 horsepower at 450 rpm. Speed is controlled accurately between 90 and 410 rpm. In place of dissipating the slip in conventional resistors or liquid rheostats, the Clymer system of speed control is used. The technical aspects of this system of speed control have been described in detail in other papers.[1,2] The system (Figure 4) consists essentially of a constant-speed motor-generator set and a variable-speed motor-generator set controlled by amplidynes. All slip energy is returned to the line minus machine losses, which results in a high efficiency. The rotor of the main drive motor is connected directly to the variable-speed set. The d-c machines on the constant-speed and variable-speed motor-generator sets are series-connected to form a loop circuit. Low starting kilovolt-amperes for this system are obtained by starting the constant-speed set. After this set has reached synchronous speed, the variable speed is brought up to provide 60 cycles, and, with proper excitation applied at the rotor, the line voltage and frequency on the stator of the main drive motor are matched accurately. The running circuit breakers then are closed. After synchronization, the speed at any instant is proportionate to the difference between the stator and the rotor frequency. Speed variations are accomplished by varying the fields of the d-c machines in the loop circuit and can be maintained within less than 1/4 of 1 per cent. Amplidynes are used to maintain automatically constant potential, frequency, and power factor.

Temperatures as low as 67 degrees below zero are obtained in the altitude wind tunnel by means of the world's largest refrigeration plant with a capacity equivalent to 20,000,000 pounds of ice daily. The refrigeration compressors are operated by 14 1,500-horsepower induction motors. An additional 2,300 horsepower in smaller motors is required to refrigerate the make-up air, making a total of 23,300 horsepower required for refrigeration purposes. The tunnel is evacuated to approximately one-ninth of sea-level pressure by four 1,750-horsepower slow-speed synchronous exhausters. Under certain conditions the combined demand for the altitude wind tunnel including refrigeration and exhauster equipment can rise as high as 42,000 kw. The Icing Research Tunnel is used to investigate icing conditions; its fan is driven by a 4,160-horsepower motor. This motor is a wound-rotor induction motor and by proper switching is driven from the same Clymer system of control that supplies the altitude wind tunnel drive motor.

The 8- by 6-Foot Supersonic Wind Tunnel. The 8- by 6-foot supersonic wind tunnel was constructed to provide a means of studying large full-scale jet engines in operation at speeds up to twice the speed of sound under conditions of temperature and pressure simulating flight conditions at about 35,000-foot altitude. Air is dried and then

forced through the tunnel by an 18-foot-diameter axial-flow compressor (cover photo of this issue) having seven rotor stages and nine rows of stationary blading with a total of approximately 1,000 blades. The compressor has a capacity of approximately 2,250,000 cubic feet of air per minute at a pressure ratio of slightly less than 2. Three large wound-rotor motors (Figure 5) mounted in tandem on a single shaft provide a total of 87,000 horsepower to drive the compressor at speeds that can be controlled accurately between 770 and 880 rpm. Speed control is obtained by means of amplidynes operating liquid rheostats connected to the rotors. The technical details of this system of speed control have been described in detail in other papers.[2,3]

Engine Research Building. In contrast to the tunnel type of research facility just described is the multicellular type of test facility such as exists in the Engine Research

Figure 5. 87,000-horsepower drive system for the 8- by 6-foot wind tunnel

Building of the Lewis laboratory. This building houses a large number of test cells and tanks connected to common air systems, which permit almost continuous running of the air supply equipment with proper scheduling of the test cells, since shutdown time is required for change of models and alterations to models. The common air systems use a total connected capacity of approximately 44,000 horsepower, which supply air under controlled conditions of temperature and pressure to simulate conditions of altitude up to 60,000 or 70,000 feet. Typical of the newer equipment attached to the air systems are the altitude exhausters shown in Figure 6.

Many of the most interesting problems have occurred in connection with the test cells and tanks attached to the Engine Research Building air systems. In designing control equipment for the test engines it is necessary to strike a compromise between absolute safety in operation and the need for obtaining data in the realm of unconventional operation. The engine under test must be protected against damage to itself or connected equipment which would result in shutdown and lost time. The sudden stopping of a test setup could cause undesirable dumping of large blocks of power. Protection frequently provided includes bearing temperature and overspeed devices, blade tip clearance indicators, flame detection equipment, and, when the hazard exists, automatic carbon dioxide discharge in the event of fire. All of this protection is interlocked electrically with the engine controls or with warning panels.

The shift from reciprocating to jet engines near the close of World War II resulted in a number of problems. Jet engines required higher speeds, higher power, and generally higher operating temperatures than the conventional reciprocating engine. As a result the dynamometers used for reciprocating engines were inadequate for jet engines, and in a number of instances wiring devices and wire for use in high-temperature areas had to be found. Sometimes it was necessary to resort to glass-insulated wire for temperatures ranging as high as 600 degrees Fahrenheit.

VARIABLE-FREQUENCY SYSTEM

DRIVE MOTORS for research on compressors and turbines require high horsepower and accurate speed control over a wide range of speed. These requirements increased from 4,000 horsepower for reciprocating engine tests to 9,000 horsepower for the early jet engines a few years ago, and now to 15,000 horsepower. Since the setup time of many research tests is a considerable portion of the total time, a flexible source of power can be used for a number

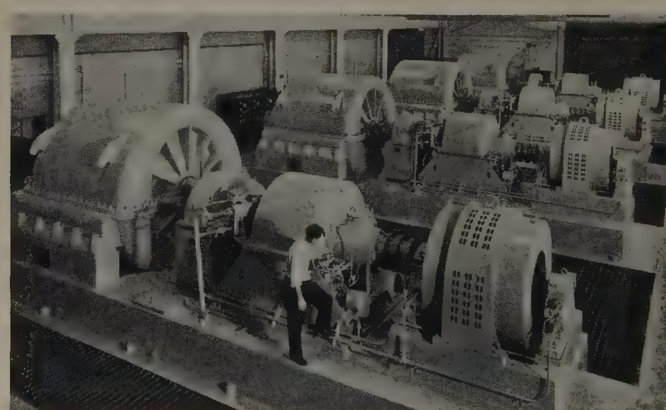

Figure 6. Exhaust equipment for altitude research air systems

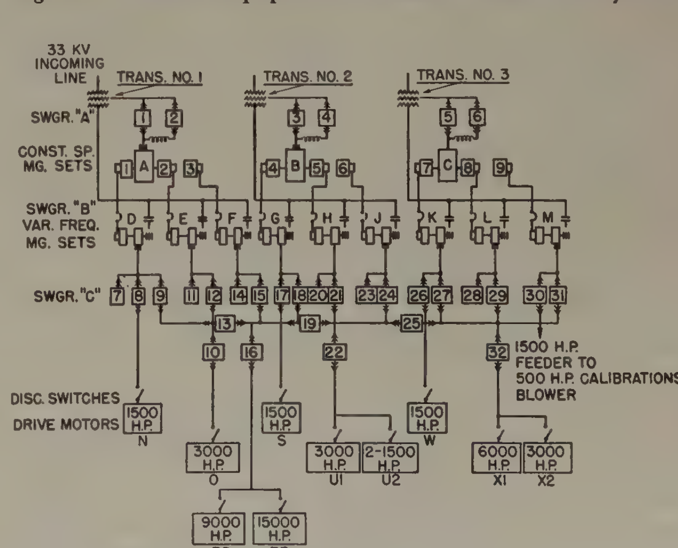

Figure 7. Circuit of the variable-frequency power plant with selective switching

of setups where they are within a given area and the requirements are similar. For this purpose a variable-frequency power plant (Figure 7) with selective switching was designed to provide 10 to 120 cycles at constant torque. The drive units for the research operations which

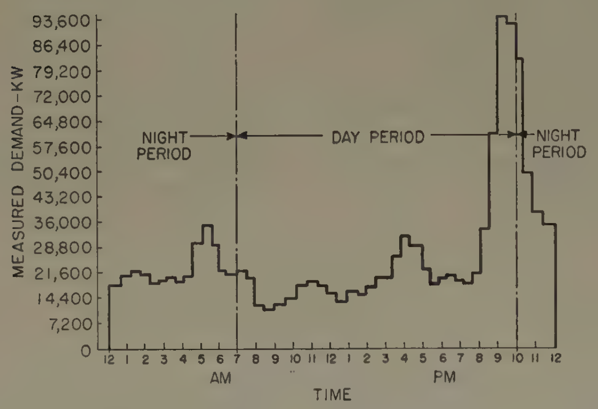

Figure 8. Demand curve for the laboratory for August 24, 1950

use this variable frequency are 1,500-, 3,000-, 6,000-, and 9,000-horsepower induction motors and a 15,000-horsepower synchronous motor. Top speeds for these motors are 1,800 rpm for the 6,000- and 9,000-horsepower units, and 3,600 for the 1,500-, 3,000-, and 15,000-horsepower units. These units are used as motors when driving compressors, or as generators to absorb power when operating with gas turbines. For purposes of flexibility the variable-frequency power plant is divided into three groups, each consisting of a 3,750-kva 3-winding transformer, a 2,650-horsepower constant-speed motor-generator

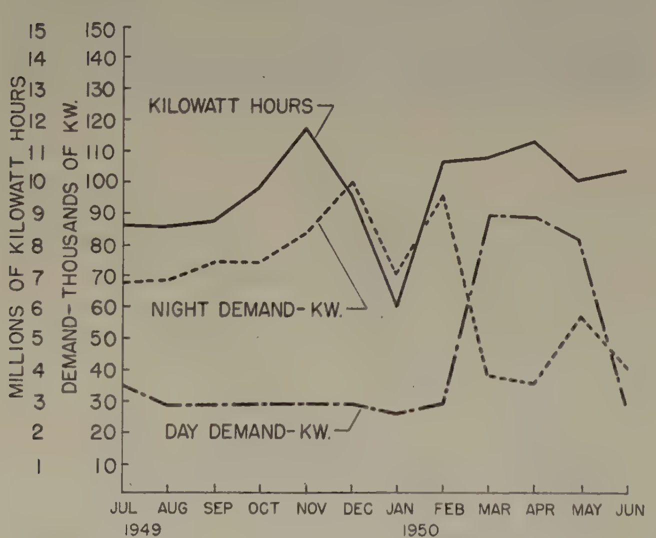

Figure 9. Power requirements for the fiscal year 1950

set, and three 1,500-kw variable-frequency motor-generator sets. The secondary winding of each transformer provides 6,600 volts for the synchronous motor of the constant-speed set and the tertiary winding provides 790 volts for the slip rings of the variable-frequency generators. Each constant-speed motor drives three d-c generators, one for each of the three d-c motors on the three variable-frequency motor-generator sets. For one direction of rotation of the variable-frequency set, the frequency of rotation and the 60-cycle frequency impressed on the 790-volt rotor winding are subtractive, and as the speed drops from full speed to standstill, the output frequency of the stator varies from 10 cycles to 60 cycles. When the direction of rotation is reversed, the frequencies become additive, generating output frequencies of from 60 to 120 cycles. The variable-frequency sets are parallel-connected in various combinations by means of the selective switchgear. One set operates a 1,500-horsepower motor, two are parallel-connected for the 3,000-horsepower unit, and up to all nine sets are used for the 15,000 horsepower unit. Frequency at a given setting is maintained within 1/4 of 1 per cent by amplidynes. The speed of the driving motors is stepped up by means of gear boxes to speeds ranging from 9,000 to 40,000 rpm.

DEMAND SCHEDULING

The two types of aircraft engine research facility which require large amounts of power are: first, the wind tunnel type, which usually has one test section with facilities tailored to its particular requirements; and second, the test cell type, which consists of a number of rooms, all served by a central air system. Running the first type of equipment results in large peak demands and relatively short running time. The second type of equipment has rather wide variations in demand, fairly good diversification, and relatively long running time. This makes the predictions of power requirements somewhat difficult, as can be seen by examining the daily demand chart, Figure 8. Operation of the 8- by 6-foot supersonic wind tunnel is closely scheduled with the dispatchers of the power company. It can be run at any time during the day or night upon prior arrangement. Normally this facility can be run during the night without any difficulty with respect to power availability.

The monthly power requirements for the fiscal year 1950 are shown on the curves of Figure 9 and illustrate the variations in the use of energy that occur at the laboratory. The highest monthly use of energy to date has been 12,400,000 kilowatt-hours. With a large amount of synchronous machinery in operation, the power factor runs between 90 and 100 per cent and quite often as high as 98 and 99 per cent. When the 8- by 6-foot tunnel is in operation, the power factor drops to around 90 per cent. The present connected load is approximately 212,000 kw. The average load factor for the fiscal year 1950 is 17.84 per cent. In spite of the wide variations in load and uncertainty of operation due to unpredictable breakdowns and changes, the relations with the power company have been excellent, largely because of the close contact between the power dispatchers of the power company and the personnel responsible for operating the equipment at the laboratory.

During the period of World War II with operations scheduled to two and three shifts and with a general nation-wide shortage of power, it became extremely important that the large demands of the laboratory be

scheduled carefully. This change was accomplished by close co-operation with the power company and resulted in scheduling the large loads to coincide with the dips in power demand of the power company. An added reason for close contact was the possibility of sudden "dumping" of blocks of power in excess of 50,000 kw, which would affect the stability of the power company's system and its interconnections. This possibility was considerably increased with the completion of the 8- by 6-foot supersonic tunnel. Equally undesirable to the power company would be the too rapid starting of a large facility. Such possibilities were considered in the design of the distribution system. All circuit breakers 33 kv and higher are remotely controlled from a centrally located dispatch office. The laboratory power dispatcher has direct telephone connection with the power company's power dispatcher and with each of the major laboratory facilities. He advises the power company several hours in advance of the starting of major equipment. He likewise informs the power company as much in advance as possible of any shutdowns of major equipment whether normal or emergency. These arrangements nearly always permit the power company's dispatchers to adjust their system to the changes in load at the laboratory. This type of operation proved to be mutually satisfactory to the power company and to the Lewis laboratory. Telephone cable was used in the initial installation of the dispatching system, but proved to be vulnerable to occasional inductive surges in certain portions of the system. Later installations were made with railway signal cable, which has proved satisfactory so far.

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Some Limitations of Science

T. E. MURRAY
FELLOW AIEE

If men will not clothe the bare framework of science with the warm garments of true humanism, they will end up by making machines their god and mathematics their only dogma. They will become as ruthless as the atoms which smash each other.

ALMOST TWO YEARS have passed since I had the honor of being appointed by President Truman a member of the Atomic Energy Commission. During that time I have been engrossed largely with the problem of fissionable material. The Commission is constantly trying to evaluate and properly apply the latest atomic techniques. The time and study which such evaluations demand inevitably and recurrently prompt one to ponder about God and the atom and how society and our individual lives ought to be ordered in this atomic age.

I am convinced that a great many of our complaints today are directed toward things of our own making; things that would be different if we only made up our minds to order them so. The world continues to sow wars and reap wretchedness. When wars threaten or come, we complain bitterly. But we live and think things that breed discontent, distrust, and fear. We trade in ill-will and hatred. We violate, with abandon, many, if not all, of the laws of the Creator, and then call on the atomic bomb to save us from our own folly!

THE ATOMIC BOMB

INDEED, THE ATOM BOMB has postponed, and I pray indefinitely, the day of final reckoning. The men of science have contributed much to ward off the great holocaust—how much only history will tell. But let us not forget that sole dependence on science as civilization's savior is bound to prove futile. Life and culture are larger than the expanding universe of science. This is no reflection on science. It is simply another way of saying that science is for man; man is not for science.

We all recognize and appreciate deeply the fact that men of modern laboratories have exhibited a dazzling ingenuity. Their magnificent contributions touch every phase of living. Through their efforts, yesterday's luxuries have become today's necessities. The list of benefactions is endless; yet progress has just begun.

Scientists have placed in the hands of men power which beggars even the imagination that fashioned the story of Alladin's lamp. If chemical discoveries, machines, and atomic energy were all that were needed to make men happy, our earth should be Elysium. Yet for all our power over nature, there is no father, sitting comfortably at home tonight and pondering the welfare of his family, who does not have occasional dark moments as the thought of atomic bombardment momentarily intrudes upon his planning. He knows the tremendous area coverage of

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Essentially full text of an address presented at the American Institute of Chemical Engineers Meeting, Atlantic City, N. J., December 2–5, 1951.

T. E. Murray is a member of the Atomic Energy Commission, Washington, D. C.

the atomic bomb. He also knows that equal area coverage by conventional TNT bombs would be vastly more costly not only in dollars but in manpower for deliverability.

This statement becomes crystal clear to anyone who has been privileged to witness, at close range, an atomic test. I have stood within 9 miles, not of our biggest, but of one of our sizable nuclear explosions. I stood riveted, dumbfounded, awe-stricken. I had a feeling I might be looking into eternity. For space is annihilated. Time is measured in millionths of seconds. Temperatures approaching those at the center of the sun are produced. The sensation, emotion, and reaction that one feels are difficult to translate into words. There is an empty feeling in the pit of the stomach when, out of the blackness and stillness of the night, a great ball of light plunges into vision. Opaque glasses, so dense that ordinary light does not penetrate, seem to melt before one's eyes. You count 1, 2, 3 and then remove the glasses. Now the fire-ball surpasses summer's mid-day sun. It represents energies greater than ever before released by man.

The familiar mushroom is there. That might remind you of a highly colored medical picture of the human brain. A rush of heat, like the opening of a furnace door; a crash that seems to break the ear drums and knocks those unprepared off their feet. And all this at 9 miles away. The awesome mass, loaded with its cargo of radioactive dust, rises rapidly skyward to sail forever around the world and make its presence known wherever it goes. For some of its particles will give off radioactive rays for 20,000 years or more, others for 40,000 years or more.

LOOK BEYOND SCIENCE

One might well ask are we not perhaps playing with things that belong only to God. But we can and should get some comfort, in this cold war of nerves, from our stockpile of weapons. We constantly are being asked—and rightly so—how do we stand in this atomic race for survival? That is like asking: "Watchman—what of the night?" I can answer: "All seems well." Our search for more ore is proving successful; our efficiency in the use of fissionable material is constantly increasing. Our atomic weapon techniques are improving with each new test, and testing is prerequisite to progress. Unfortunately the Russians know this too, but we hope and pray that we are well in advance of Moscow and diligent and foresighted enough to maintain our lead in all fields of atomic endeavor.

Recently we have heard and read much about atomic weapons and secret weapons. Our national habit of reading comic books makes us easy marks for this alluring approach to national security. But it has its tragic side. One might well interpret the newsworthiness of recent speculations about secret weapons as a sign that already we have grown tired of the cold war struggle and are looking for an easy way out. Let me assure you there is no such primrose path ahead. There are any number of military jobs that cannot be handled by 1951 models of atomic bombs.

The scientists have brought us time—time to think clearly, time to reflect, time to act wisely and prudently, time to pray. But the hourglass runs out. It may be later than we think. Meanwhile what is needed is for all of us to look beyond our stockpile of weapons, beyond atomic submarines, atomic aircraft, beyond chemical discoveries, even beyond science.

Long ago it was recognized that science is a tool. It is a means, not an end or a false god. To use this tool well, we must know something of its potentialities and something of its limitations. We have heard much about the prowess of science; now let us consider some of its limitations.

LIMITATIONS OF SCIENCE

The most obvious limitation contrasts two kinds of control: control over matter and control over man. Science can give man mastery over matter; it cannot give man control over himself. Science has its distinctive method. Like all methods, it has its appropriate and inappropriate applications. It involves experiment—with tools, machines, and chemicals. But you cannot, without a kind of sacrilege, experiment with the souls, lives, and honor of men.

Then again science never reaches ultimates. It becomes a process of smashing atoms and then of endlessly smashing the parts into which atoms are broken. Thus it never comes to that ultimate particle which is this side of nothing. It "explains" matter by simply dividing it into ever smaller subatomic particles: electrons and protons yesterday; neutrinos and mesons tomorrow. While it explains much, there is a sense in which, we can say, it is forever deferring explanation. It is always postponing the ultimate reason: the element by the molecule; the molecule by the atom; the atom by the nucleus; the nucleus by—"The good Lord only knows—."

Can we get any nearer the good life by thus constantly raising atomic dust, and giving that dust Greek derivative names to mask our ignorance? While progressing, without end, in the knowledge of broken things, it will never properly answer such fundamental questions as: What is man? What is his destiny? Who is God?

Now that it is possible for us to see farther out into space and deeper into the pointed focus of the atom's nucleus, the body of this world has grown larger, as it were. For that very reason it needs, in the fine phrase of Bergson, a "surplus of soul." Such a surplus cannot be supplied from a laboratory.

We often talk of science as a matter of closed systems. Action equals reaction. Input must equal output. That is why mathematical equations best define the laws of science. One member always precisely equals the other. But life and love are not mere matters of equations. Sacrifice and generosity are what they are just because their input does not equal output. To be generous, to be charitable, means that the reaction is greater than the action. In this field, man can give more than he has received. Indeed by virtue, whether intellectual or moral, man spends but still retains; or rather, he gains in the very act of spending.

Religion and philosophy, on the other hand, can be thought of in terms of open systems. They are not limited to chemical reactions, machines, atomic structures, or planetary systems. They are not even bounded by the

wanderings of the farthest stars. Nor are they confined within vast areas crossed by the lightning flashes of men's best minds. Religion and philosophy transcend all boundaries. They bring us, in one direction, to God, and the other direction, beyond tomorrow's tiniest division of submicroscopic particles. They take us as far as possibility itself goes. That is why we say they are not closed systems. They are open, open to all reality.

However useful science is to investigate the privacy of tiny chambers called atoms, it is all but useless to investigate the inner and higher life of man. You cannot examine free-will in a test tube. Yet, much of what man does for weal or woe springs from this inner life of free choice. Nuclear energy can explode with uncontrollable force. The occasion for its explosion may be controlled by evil or by good men.

Atomic bombs are only dangerous because some atomic men cannot be trusted. Science cannot save men from themselves, any more than society can. Rather, it is individual men who must save society and save themselves. If men will not live by virtue, they may have to die by power! The crisis we face today comes from the greed of men and their will to power regardless of conscience. The responsibility for the crisis is man's refusal to submit his behavior to reason and to reason's God.

TEMPTATIONS OF SCIENCE

In addition to these limitations, there are certain temptations which science does not cause but for which science is an occasion. There is an obvious failing of man in that he is an easy subject of myth-making. He is suggestible in the face of Utopian dreams. He has a natural inclination for comfort and ease. This is the inclination in men which demagogues foster, so that a life of effortless ease might become the goal of men's ambitions. Men want easy money and ready comforts. They want gadgets and conveniences. The glories of science tempt men to use them only for the life without effort, for the life which makes no demands, asks no sacrifice.

Others are tempted to make a religion of science. But such a religion becomes a godless vacuum which substitutes atoms, protons, electrons, for faith in a Creator.

Yet, precisely because this is not a random world tossed by chance upon the gaming table of space, precisely because all the things that are were made by God, man's attention must never be so focused on science as to neglect religion and philosophy which can direct our lives according to right reason and charity. Many scientific facts known today were known only to our Creator but a short time ago. That in itself is enough to make man humble.

If men will not clothe the bare framework of science with the warm garments of true humanism, they will end up by making machines their god and mathematics their only dogma. The rising tide of paganism in the Western world will make our civilization cold and ruthless, as cold as interstellar spaces, as ruthless as atoms which smash each other.

Life and culture need modern science; but they need even more the qualities that make life genial and human. Times come for all of us when we must lift our thoughts not only above the swirl of matter but even above plant life and animality. Man needs an appreciation of why he lives and loves. He must be brought into contact with things to live for, and even things to die for. Glittering galaxies and the dizzying circuits within the atom are not, for all their reality, what a man can really live for or be willing to die for.

Let us never forget that we will have bought our conquest of matter at too high a price if it robs us of that humility which enables us to detect in every majestic scientific discovery the pathways and the laws marked out by the Divine Architect.

Army Builds Inexpensive Anechoic Laboratory in Maryland

To achieve an absolutely clean environment for acoustic measurements, the Protective Division of the Chemical and Radiological Laboratories has constructed an anechoic laboratory at the Army Chemical Center in Maryland. The laboratory will be used in determining the acoustic properties of the gas mask facepiece so that better speech transmission for wearers of the mask can be provided.

The echoless room, illustrated in the photograph, is of the baffle type. The wall and ceiling of the room are hung with straight hair felt baffles of predetermined length. As the frequency of sound absorbed is a function of the length of the baffle, the room can be tailor-made to reduce sound reflections only in the useful frequency spectrum. Because the hair felt is relatively inexpensive and requires no elaborate supporting structure, this room is much more economical than other types such as those using large numbers of Fiberglas wedges to absorb sound. Total cost of materials used was less than $1,000.

Capacitor Switching Phenomena

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THE SWITCHING of capacitors differs from other switching by causing relatively large surge currents and possibly overvoltages. The performance of circuit breakers in this service has been found by recent experiments to depend on the power supply system as well as on the size of the capacitor banks. When circuit breakers open with no delayed restriking of the arc, they avoid the possibility of causing undesirably high current and voltage surges.

The time during an opening operation when the arc first extinguishes may be determined by the voltage drop produced by the capacitor current flowing through the source impedance. This voltage drop is a fraction of the drop which would occur in the case of a short circuit, and it produces a component of the transient recovery voltage of the same natural frequency or other characteristics but with a lower amplitude. Consequently, the initial voltage tending to restrike the arc is similar to the recovery voltage in a lower voltage inductive circuit.

If the natural frequency of the circuit on the source side of the circuit breaker is in the order of several thousand cycles per second, the initial part of the transient recovery voltage may cause the arc to reignite at early current zeros with no significant pause in the current wave. The average time to the first extinction of the arc was almost directly proportional to the product of the source inductance and the capacitor current, unless the circuit breaker and circuit produced arc extinction at the first current zero.

A circuit breaker does not restrike if, at the current zero when the arc extinguishes and during the following half-cycle, the dielectric strength which it develops is greater than the transient recovery voltage during that period. If the arc extinguishes but the dielectric strength is exceeded by the recovery voltage, a restrike occurs. This growth of dielectric strength depends on several factors such as type of interrupter, initial length of gap, forced oil flow, forced-air flow, speed of contacts, and amount of gas from the arc remaining in the gap.

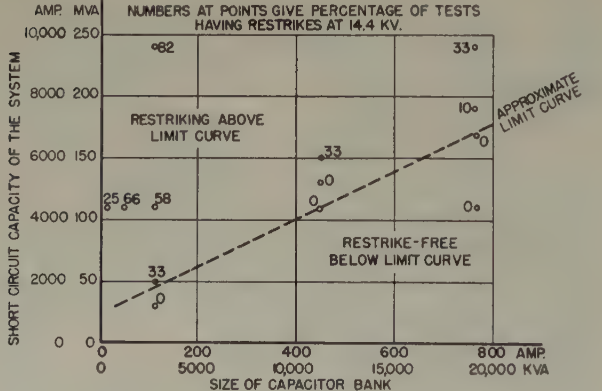

Figure 1. The operation is restrike-free if the maximum possible short circuit at the capacitor location is below a critical value indicated by the curve. ("De-ion" grid oil circuit breaker switching a capacitor bank at 14.4 kv and having 7.5 feet per second contact speed)

The recovery of dielectric strength immediately after current zero, for a given circuit breaker and in the range of capacitor currents, was found by test to be almost directly proportional to the contact separation and independent of the current interrupted. The recovery during the following half-cycle depended on the current which had been interrupted, probably because of varying amounts of gas in the arc space.

Some circuit breakers are restrike-free under any condition. For example, those having forced flow of the extinguishing medium may recover dielectric strength fast enough to prevent restriking at any capacitor current or with any contact separation at the time of arc extinction. Moreover, many power circuit breakers which recover dielectric strength too slowly at short contact separations will operate restrike-free in some locations. This occurs if the part of the transient recovery voltage produced by the voltage drop in the source impedance caused by the capacitor current prolongs arcing until a contact separation has been reached at which the circuit breaker develops dielectric strength faster than the recovery voltage applies potential. This critical voltage drop will be a function of current for a given circuit breaker since the recovery of dielectric strength during a half-cycle is dependent on current and circuit-breaker characteristics.

The voltage drop is a significant value, representing approximately the voltage regulation caused by the switching. The voltage drop occurs in the source impedance and therefore is related to the maximum possible short circuit at the location.

The relation between the size of the capacitor bank and the short-circuit kilovolt-amperes, for which the disconnection of the capacitor bank is restrike-free, is shown for one circuit breaker and operating speed in Figure 1. Points below the critical line represent combinations of capacitor bank size and short-circuit kilovolt-amperes which give restrike-free performance.

During the large number of tests, about 1,500 on oil circuit breakers and 600 on magnetic air circuit breakers, many of them with restrikes, the maximum voltages reached were 2.5 times the normal crest of phase-to-ground voltage for oil circuit breakers and 2.0 times for magnetic air circuit breakers. The compressed air circuit breakers tested up to 25,000 reactive kva at 13.8 kv with and without a parallel bank operated restrike-free.

Digest of paper 51-21, "Capacitor Switching Phenomena," recommended by the AIEE Committee on Switchgear and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. Published in AIEE *Transactions*, volume 70, part I, 1951, pages 151–59.

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A Polyphase Thermal Kilovolt-Ampere Demand Meter

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THE INCREASING NEED for a low-maintenance and relatively low-cost kilovolt-ampere demand meter has led to the design of a new type of thermal meter to accomplish this purpose. The complete unit includes a 2-element watt-hour meter as well as a thermal kilovolt-ampere demand meter in the same size base as a standard 3-element watt-hour meter, see Figure 1. Circuits for which the meter is available include: 3-phase, 3-wire; 3-wire network; 3-phase, 4-wire Y; and 3-phase, 4-wire delta.

The demand unit consists essentially of a thermal ammeter and a thermal voltmeter, whose shafts are linked mechanically to read kilovolt-amperes accurately over a limited range of voltage. Both the voltage and current elements consist of pairs of bimetal springs. One spring of each set is heated, while the other serves as ambient temperature compensation.

The potential element is fed by a potential transformer. It is assumed that the voltages are balanced, an assumption which is common to all polyphase kilovar meters, $2^1/_2$-element watt-hour meters, and 3-wire single-phase watt-hour meters.

The current element is energized from a positive-sequence resistor-reactor network, which in turn is fed by current transformers. The voltages associated with the impedance drops in the network add vectorially in the proper phase and magnitude to give a resultant voltage which is proportional to the total polyphase current. This voltage is applied to a set of heaters energizing a bimetal element.

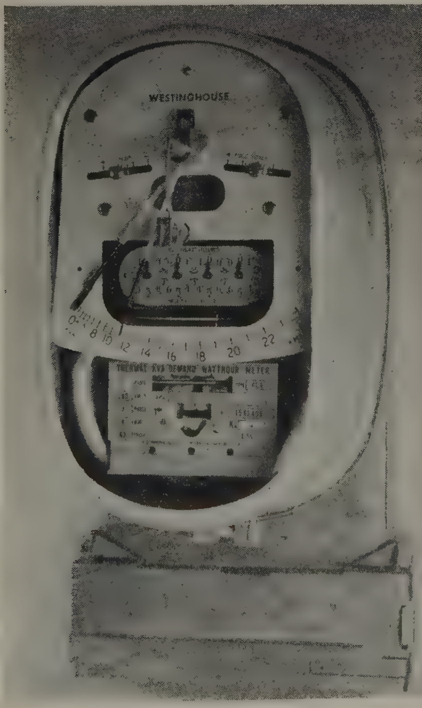

Figure 1. Meter with cover on

Figure 2. Phantom view of mechanical linkage

The way in which the voltage element modifies the deflection of the current element can be seen from Figure 2, which shows a model with a transparent dial plate. The current and voltage elements are connected together by means of a link between arms on the two shafts. The linkage is so arranged that the deflection of the current element is not affected by changes in voltage at zero current, since the link is in line with the current arm and therefore exercises no torque on the current-element shaft. As deflection of the current element increases, however, the influence of the voltage element increases proportionally due to the angular relation. The net deflection, therefore, represents the product of current and voltage. Since the two elements are electrically independent, they obviously are not affected by changes in power factor.

To facilitate the arrangement of the components, the indicating and maximum demand pointers are carried on a separate shaft which is geared to the current element. The ratio of the gears is 1-to-1 to minimize backlash and friction.

In addition to the usual watt-hour and thermal meter adjustments provision is made for positioning the arms correctly and for balancing the sequence network.

This meter has the advantage of measuring directly the two quantities desired—kilovolt-ampere demand and kilowatt-hours. It fulfills a need for a lower-priced low-maintenance kilovolt-ampere demand meter in a compact unit of relatively small size. Therefore, it should be instrumental in extending the range of loads over which kilovolt-ampere demand metering is practical.

Digest of paper 51-323, "A Polyphase Thermal KVA Demand Meter," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Experience with Aeolian Vibration in Overhead Ground Wires

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Observations indicate that wire tension is the most important cause of fatigue failure in overhead shield wires. These observations, and some of the remedial measures taken by one utility, are the subject of this article.

IN 1948 THE Oklahoma Gas and Electric Company began using the extra-high-strength 7-strand galvanized steel wire being offered by the steel wire manufacturing companies for overhead shield wires in the construction of some of its H-frame and steel tower transmission lines. Use of the extra-high-strength (EHS) wire made it possible to install the shield wires with less sag, thereby obtaining more mid-span separation between the shield wires and the conductor and, therefore, better shielding from mid-span lightning strokes than with the same size of high-strength (HS) wire.

On some of the lines where EHS wire was installed at a tension of approximately 28 per cent of the ultimate breaking strength, broken strands were found at the suspension clamps within a few months after the wire was installed.

The purpose of this article is to present the pertinent details of the installation, the location with respect to prevailing winds, the terrain, the nature of the failures, and the remedial measures that have been taken.

Figures 1 and 2 show the H-frame type of structures on which the EHS wire was installed. The transmission map of Figure 3 shows the location of the shielded H-frame and steel tower transmission lines constructed since 1940 with reference to prevailing summer and winter winds and a brief description of the terrain. On this map the lines are referenced by number to Table I which shows the type of structure, date of construction, span length, type and size of shield wire, shield wire tension as originally installed, and tension of shield wires on lines where they have been resagged and armor-rodded since January 1950.

Although noise from aeolian vibration had been observed at the structures on the tower line section of the Harrah-Oklahoma City line and the Ponca City-Enid H-frame line, the first indication of serious trouble was the week of January 20, 1950, when a shield wire on the Ponca City-Enid line broke at the suspension clamp and fell.

An inspection was made of the two 5/16-inch EHS shield wires on 61 structures at the Enid end of the line and it was found that one or more of the 7 strands were broken at 100 out of 122 suspension clamps inspected. Conditions found were as follows:

- 0 strands were broken at 22 clamps
- 1 strand was broken at 51 clamps
- 2 strands were broken at 34 clamps
- 3 strands were broken at 5 clamps
- 4 strands were broken at 10 clamps

All the strand breaks were clear breaks, at or near the point where the outer edge of the keeper applies pressure to the wire (see Figure 4), except three which were nearer the center of the clamp, indicating that vibration fatigue was the cause.

Although the shield wire in this part of the line had been in service only 20 months, some of the strands evidently had been broken for some time, as the broken ends were rusty and some of the rust had washed down into the clamps. In most cases ends of the broken outer strands had separated about 1/8 inch at the break. The center strand was found broken at a few clamps. In these cases the break was just a crack—the strands had not separated a measurable amount. Metallurgical tests showed the wire to be in conformity with American Society for Testing Materials specifications.

Inspections of the shield wires on the Cleo-Woodward line and steel tower section of the Harrah-Oklahoma City line also revealed broken strands at some of the clamps, although the lines had been in service only about 5 months. Since the shield wires for these lines were purchased at different times and from different manufacturers, it was decided that the wire was not defective.

REMEDIAL MEASURES CONSIDERED

BREAKAGE OF STRANDS at the clamps had progressed so far on the Ponca City-Enid line that it was necessary to repair or replace the shield wires as soon as possible. Obviously, in either case it would be necessary to reduce the vibration at the clamps or adequately protect the wire at the clamps from vibration, or both.

Replacement of the wire would be costly and it would take considerable time to get the job completed, thus prolonging the hazardous operating situation.

Inasmuch as the American Steel and Wire Company had furnished the shield wire for this particular line and their preformed armor rods had been installed recently at the suspension clamps on an old 1/0 (7-strand) copper 66-kv line to strengthen the wire where it had been burned in the clamps, their advice was solicited regarding the shield wire problem.

They promptly furnished test data which showed that 56-inch-long Amergrip splices, which are coated with an abrasive to supplement the gripping action of the rods

Essentially full text of a conference paper recommended by the AIEE Committee on Transmission and Distribution and presented at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950.

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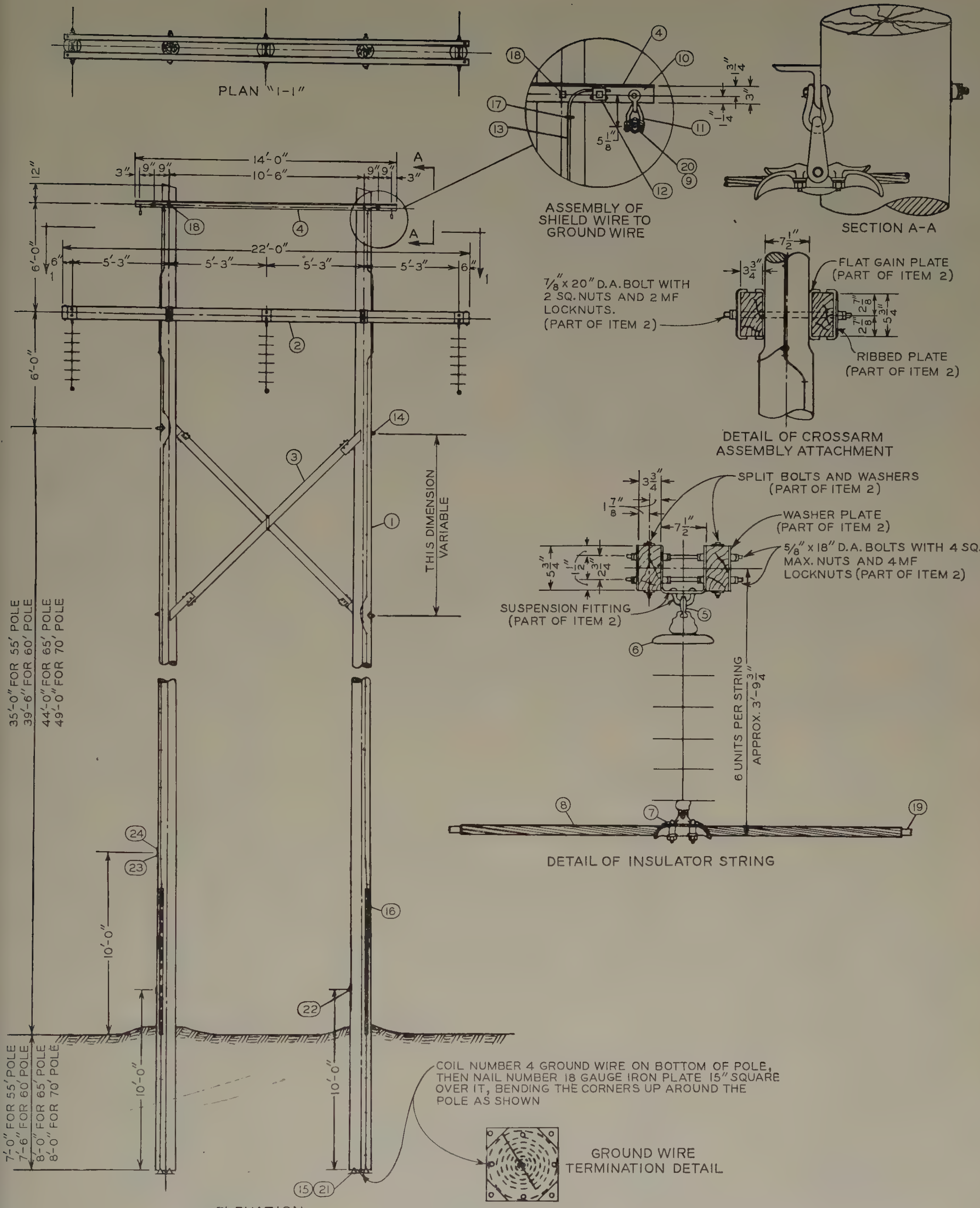

Figure 1. A 66-kv H-frame tangent structure on which extra-high-strength steel overhead shield wires were installed

themselves, provided a splice that was stronger than the EHS wire. Their vibration test data indicated that if the wire was protected at the clamp with Amergrip preformed rods, its resistance to vibration fatigue would be increased approximately ten times.

It was believed that the higher tension at which the

shield wires on some of these new lines were installed was causing excessive vibration, because shield wires installed on some of the company's lines with an initial tension of about 15 per cent had shown little or no tendency to vibrate, and no fatigue breaks had developed during 20 years of service. It also was believed that the preformed armor rods might have an appreciable damping effect.

VIBRATION OBSERVATIONS

To verify these assumptions, some experimenting was done on 1 mile of the Ponca City-Enid line near the Enid terminal. One of the two shield wires was resagged to a tension of 15 per cent of ultimate strength at 60 degrees Fahrenheit and 63-inch Amergrip armor rods were installed at some of the suspension clamps on each wire.

The line had been subjected to heavy ice loading in January 1949, and by measurement of sags it was found that the shield wires had attained approximately their final sag and tension.

Thus, after resagging one of the shield wires in a 1-mile section, the sags and tension in the two wires at 60 degrees Fahrenheit were:

	Sag		Tension	
	650-Foot Span	750-Foot Span	Pounds	Per Cent of Ultimate Strength
Shield wire as originally installed	3 feet 10 1/2 inches	5 feet 2 inches	2,800	25
Resagged shield wire	6 feet 5 1/2 inches	8 feet 7 inches	1,680	15

The span lengths in the test section were 625, 675, 650, 650, 575, 675, 675, and 725 feet.

Observations were made during a period of several days at temperatures varying from 37 to 74 degrees Fahrenheit and wind velocities ranging from 8 to 35 miles per hour.

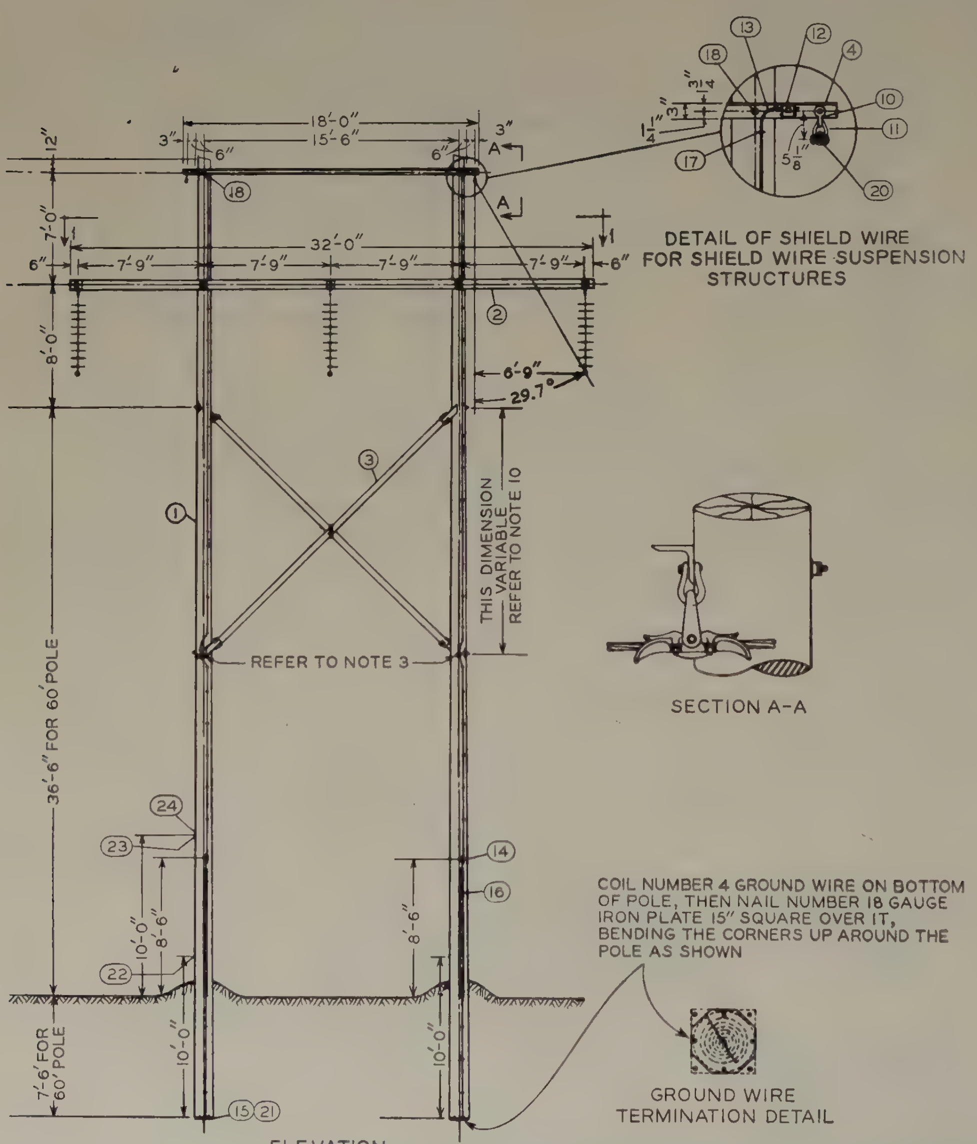

Figure 2. Another H-frame type structure. This is for a 138-kv line using extra-high-strength steel shield wires

Linemen were stationed at the tops of the poles of the structures in adjacent spans. They compared the vibration in each wire by placing their fingers on the upper side of the wire and reported their observations to men stationed on the ground.

It was found that there was only a small amount of vibration in the resagged wire at the temperatures from 37 to 74 degrees Fahrenheit and wind velocities of 8 to 25 miles per hour, whereas the other wire vibrated throughout this range of temperatures and wind velocities. In some cases the vibration in the tighter wire was so violent that it caused a loud rattle to occur at the clevis pin attachment to the suspension clamp.

The vibration was not only large in amplitude but also high in frequency. Figure 4 shows how the violent vibration caused wearing of the surface of the clevis pins, cotter keys, and surfaces of the clamps in some cases.

The worst vibration occurred at wind velocities from 8 to 15 miles per hour with the wind perpendicular to the line. When the wind velocity reached 30 or 35 miles an hour, the vibration subsided.

Table I. Summary of H-Frame and Steel Tower Transmission-Line Overhead Shield Wire Installations

Number on Map	Name of Line	Miles	Date Constructed	Structure	Normal Span, Feet	Steel Shield Wire, Inches Diameter	Ultimate Strength of Wire, Pounds	Tensions at 60° F, Per Cent of Ultimate Strength: Stringing	Final*	Remarks
1	Harrah-Guthrie 66 kv	28.14	1930	H-Frame	600	3/8 HS	10,800	15.2	15.2	No shield wire difficulties
2	Belle Isle-Reno St	10.38	1930	Steel Tower	650	3/8 CW	11,340	16.0	15.0	No shield wire difficulties**
3	Harrah-63rd St 66 kv	5.55	1937	H-Frame	650	5/16 HS	8,000	9.12	8.53	No shield wire difficulties
4	Enid-Waukomis 66 kv	6.6	1941	H-Frame	650	5/16 HS	8,000	9.12	8.53	No shield wire difficulties
5	Sapulpa-Tulsa 66 kv	4.25	1942	H-Frame	650	5/16 HS	8,000	9.12	8.53	No shield wire difficulties
6	Ponca City-Enid 138 kv	49.2	May-June 1948	H-Frame	750	5/16 EHS	11,200	27.9	25.0	Resagged for 15-per cent final tension and armor rodded
7	Ardmore-Russett 66 kv	18.84	Aug. 1948	H-Frame	800	3/8 HS	10,800	26.6	23.5	Has not been inspected
8	Okla City-Edmond 66 kv	8.58	Feb. 1949	H-Frame	800	5/16 HS	8,000	18.5	15.9	Has not been inspected
9	Mustang-Bdwy-10th St 66 kv	1.25	Mar. 1948	H-Frame	600	3/8 EHS	15,400	26.9	25.0	Resagged for 15-per cent final tension and armor rodded
10	Harrah-Okla City 138 kv	10.05	July 1949	H-Frame	900	5/16 EHS	11,200	28.2	25.0	Resagged for 15-per cent final tension and armor rodded
11	Harrah-Okla City 138 kv	5.28	Aug. 1949	Steel Tower	900	5/16 EHS	11,200	28.2	25.0	Resagged for 15-per cent final tension and armor rodded
12	Russett-Brown 138 kv	18.58	June-July 1949	H-Frame	750	5/16 EHS	11,200	27.9	25.0	No shield wire difficulties***
13	Enid-Clyde 66 kv (at Enid)	2.5	June 1949	H-Frame	550	5/16 EHS	11,200	13.2	12.5	No shield wire difficulties
14	Cleo-Woodward 138 kv	52.7	Aug.-Sept.1949	H-Frame	800	5/16 EHS	11,200	23.0	21.5	Resagged for 15-per cent final tension and armor rodded
15	Moffett-VBI 66 kv	8.33	Jan. 1950	H-Frame	750	5/16 EHS	11,200	27.9	25.0	No shield wire difficulties****
16	Guthrie-Guthrie Tap 66 kv	1.41	Mar. 1950	H-Frame	800	3/8 HS	10,800	18.2	16.0	Has not been inspected
17	Mustang-Bdwy 66 kv	9.6	May 1950	Steel Tower	1,000	3/8 EHS	15,400	17.1	15.0	Has not been inspected

* Final tensions at 60 degrees Fahrenheit after being subjected to heavy loading (1/2-inch ice and 8 pounds per square foot wind load at 0 degrees Fahrenheit).

** All points of supports were carefully inspected in February 1950 and no strand breaks were found.

*** A spot check inspection of 18 structures in June 1950 showed no strand breaks.

**** A spot check of 9 structures in July 1950 revealed no strand breaks.

The preformed armor rods had a noticeable damping effect. By feeling the wire with the hands, it was estimated that the amplitude at the edge of the suspension clamps was one-half to one-third the amplitude at the end of the armor rod (31 1/2 inches out from the center of the clamps).

These observations indicated that if the sag in the 5/16-inch EHS shield wires was increased 3 feet 5 inches (750-foot span), thereby reducing the tension from 2,800 pounds to 1,680 pounds (at 60 degrees Fahrenheit), the amount of vibration would be relatively small and the resagged wire would probably be comparable in this respect to older installations which had given no indication of vibration fatigue after 20 years of service.

Therefore, it was decided to resag the wires to 1,680

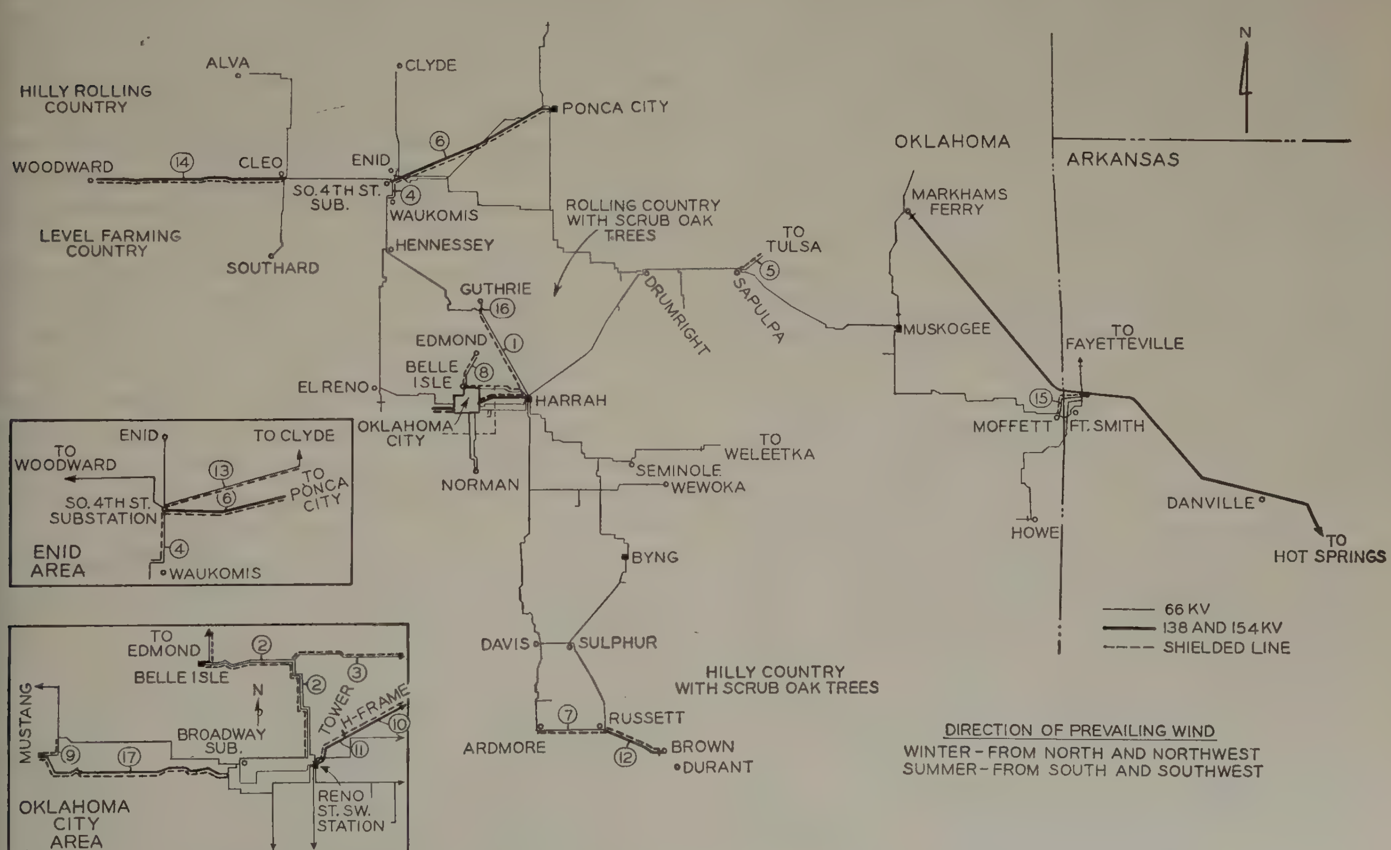

Figure 3. Transmission map showing the location of shielded H-frame and steel tower transmission lines constructed since 1930

pounds' tension and to repair and restore them to their original strength by the convenient and economical method of installing 63-inch preformed Amergrip splicing rods at all of the former suspension clamp locations.

REPAIR AND RESAGGING PROCEDURE

Come-along clamps connected to each end of a 7-foot flexible steel cable were clamped to the wires at a point about 3 feet from each side of the suspension clamp

Figure 4. A section of 7-strand cable showing typical breaks and some cable fittings which show signs of wear due to vibration

by the lineman to guard against his being injured in case the remaining unbroken strands should part while he was unbolting the keeper or installing the splicing rods. Then the center of the cable on this safety sling was placed over the steel arm which supports the shield wire. The next step was to remove the clevis pin, leaving the wire supported by the safety sling. After removing the suspension clamp and placing the armor rods on the wire, the sling was removed and the wire placed in a sagging dolly for the resagging operation. When the wire was resagged, care was taken to pull it out far enough so the new point of support would be at least 15 feet away from the former location on the wire.

Amergrip armor rods 63 inches long also were installed at the new point of support before the wire was reinstalled in the suspension clamps. This was done for two reasons. First, although little or no vibration could be observed in the resagged wire and the tension was now comparable with the tension in older shield wire installations which had given no indication of fatigue, it was not certain that fatigue failures would not occur eventually. Second, conventional wire suspension clamps were used for supporting the shield wires on the older lines, whereas trunnion-type clamps (Figure 1) were used for this purpose on the new lines, and there was a question as to whether or not this type of clamp might be a contributing factor in the early fatigue failures. Consequently, it was decided to give the wire the added protection afforded by the armor rods.

The same remedial measures were applied to the Cleo-Woodward line and both the H-frame and steel tower sections of the Harrah-Oklahoma City 138-kv line, because inspection revealed broken strands at some of the clamps.

By the time the work was done on these lines, the shield wires had been in service the following length of time: Ponca City-Enid line, 22 months; Cleo-Woodward line, 11 months; and Harrah-Oklahoma City line, 13 months.

Strand breakage was more extensive and a greater number of strands were broken at the clamps on the Ponca City line which had been in service longer than the other two.

The first 15 miles of the Cleo-Woodward line traverses level wheat farming country like that between Ponca City and Enid. The remainder of the route is hilly, rolling terrain. Damage at the clamps was greater in the flat country, probably due to more exposure to the wind. In the remainder of the line there was nothing consistent relative to the locations where broken strands were found. Sometimes they were found on structures at the top of a hill, and none on structures in the valley, and vice versa.

More broken strands were found on the steel tower section of the Harrah-Oklahoma City line than on the H-frame section. This was probably due to the wires being at a higher elevation and, therefore, more exposed to wind.

In some cases there were broken strands on one side of the clamp and none at the other side. In other cases, the same strand or strands were broken on both sides of the clamp. Sometimes different strands were broken at each side of the clamp.

One thing of considerable interest and importance was the fact that strand breakage seemed to be related to clamping pressure, as broken strands predominated at the clamps on which the clamping bolts were very tight.

Not only clamping pressure but also the shape and the length of the shoe and keeper may be a factor. Furthermore, it is possible that the trunnion-type clamp used on all these new lines permits more flexing of the wire than clamps on which the pivot point is well above the shoe.

As previously indicated, vibration fatigue is apt to be more prevalent in areas such as the northern part of Oklahoma where the country is level, where there is more wind, and the average temperatures are lower than in the rolling, more wooded southern part; also where the line is more or less perpendicular to prevailing winds. This seems to be the only explanation that can be offered as to why fatigue failures have not occurred as yet in the Russett-Brown line. See Figure 3 and Table I.

In conclusion, these experiences indicate that the most important factor is wire tension, and that with tensions as high as 23 to 28 per cent of ultimate strength, aeolian vibration may be so predominate and so severe in some localities as to cause fatigue failures, and the safe limit may be in the order of 15 per cent.

Furthermore, the use of preformed armor rods appears to be one of possibly other economical and satisfactory methods of rehabilitating damaged wire, and also for providing a measure of protection from fatigue at the point of support.

Requirements and Design for a D-C Null Detector

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MODERN INSTRUMENTATION requires the measurement of many variables that are expressed most readily as d-c voltages. In the apparatus described here, a reversing synchronous contactor is used to invert the error signal into an alternating potential of the power frequency. This alternating potential in turn is amplified and impressed upon the control winding of a 2-phase motor which has its reference winding continuously energized at the power frequency.

While it is evident that the combination of any periodically varying impedance and an amplifier will provide a result of the form desired, optimum functioning requires that each circuit element be designed for the specific use for which it is intended.

The d-c networks of such instruments are subject to inductive or resistive coupling with the power lines whereby alternating voltages of the power frequency are superimposed upon the circuit. The merit of an unbalance detector for a network of this class is its ability to discriminate between the d-c potentials, which represent the true unbalance conditions in the circuit, and stray alternating potentials of the power frequency which may be superimposed upon them.

Three ways in which stray voltages of the power frequency can interfere with the performance of the instrument are: error in the reading due to the presence at the motor terminals of voltage of driving phase; broadening of the neutral zone due to overloading of the amplifier by quadrature voltage; and broadening of the neutral zone due to overloading of the amplifier by harmonics of the power frequency.

The first two of these interfering effects can be eliminated by a symmetrical reversing switch. The degree of symmetry can be expressed as a per cent dissymmetry. This is defined as the difference in dwell times on alternate contacts expressed as a percentage of a complete cycle.

If a stray voltage of the power frequency is impressed upon the input of the reversing switch, the output of the switch can be shown to contain: negligible voltage of the power frequency in the driving-phase position; a quadrature voltage of appreciable amplitude; and even harmonics of the power frequency.

For small percentage dissymmetry, the magnitude of the percentage transmission of quadrature voltage can be shown to be approximately twice the per cent dissymmetry.

In the worst phase position the output contains a second harmonic having an amplitude of 85 per cent of the input amplitude. It also contains a fourth harmonic of 35 per cent and successively smaller values at all even harmonics.

If it is desired to tolerate a stray voltage 2,000 times the d-c voltage necessary to start the motor, the following four conditions must be met: 1. dissymmetry must be 0.5 per cent or less; 2. the second harmonic amplification must not exceed 1 per cent of the amplification for the fundamental; 3. the fourth harmonic amplification must not exceed 3 per cent of the amplification for the fundamental; and 4. the total phase shift must be held within 3 degrees.

These conditions have been met in the following manner:

1. A principle by which the dissymmetry may be held within 0.5 per cent is timing the switch action to the zero transitions of the supply-line voltage. If the contact position is reversed at the zero transition points or at points in consistent relation to them, the contact action will be symmetrical. In the reversing switch shown in Figure 1, this action has been produced in the following manner. The moving reed is energized by alternating current having a peak value approximately ten times that necessary to saturate the reed. This produces a square wave reversing force which reverses effectively at the zero current point. The armature mass and travel are kept small to produce armature motion that will follow the force pattern with negligible lag.

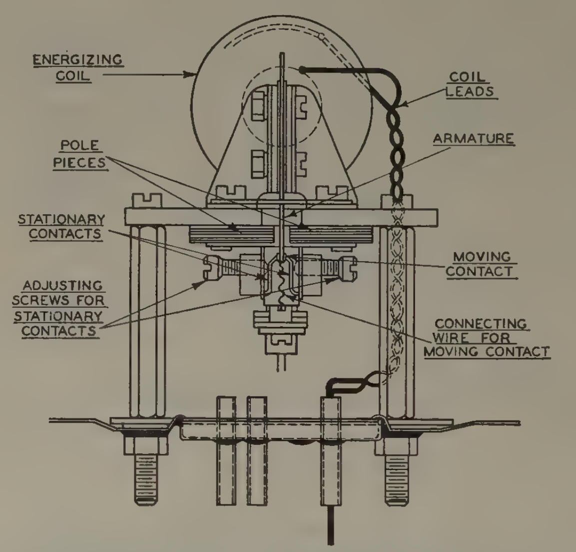

Figure 1. Reversing switch (uncased)

2. Second harmonic attenuation is provided by a parallel-T filter and low-pass resistance-capacitance filters.
3. Attenuation for the fourth and higher harmonics is provided by the low-pass networks.
4. The necessary phase tolerance requires that no elements be tuned sharply at the power frequency.

Digest of paper 51-344, "The Requirements and Design for a D-C Null Detector," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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A New Common Control Automatic Crossbar Telephone System Installed in Sweden

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A telephone system now under construction in Sweden is using this new common control crossbar system. It is particularly suitable for rural and semirural exchanges, as it can be used for all sizes of offices from 100 numbers up to large plants which are composed of a plurality of offices having 10,000 numbers each.

IN 1926 THE FIRST crossbar automatic telephone office was placed in operation in Sweden at Sundsvall for 3,500 subscribers by the Swedish Telephone and Telegraph Administration.[1] Today there are about 1,750 crossbar telephone offices in Sweden serving 260,000 subscribers. The crossbar system used in these installations is known as the standard *41* system of the direct dial controlled type and the links used for connections are progressively selected as in a step-by-step system.[2] The maintenance required to obtain reliable service in this system was so low that most of the small offices were left unattended. However, the first cost of the system was rather high. Therefore, an effort was made to design a new crossbar system which would have low first cost, low maintenance, and improved traffic facilities.

This effort has materialized in a new common control crossbar system denominated *A-204.* This system is based on ideas proposed in 1912 by Betulander and Palmgren,[3] but for some reason their ideas were not utilized practically at the time.

When information was obtained about the advantages of the American marker crossbar system, work was resumed to design a similar Swedish system. New telephone offices according to this common control crossbar system have been constructed in Sweden and others are being projected.

The new common control crossbar system can be used for all sizes of offices from 100 numbers up to the largest plants which are composed of a plurality of offices generally of 10,000 numbers each. The description presented here refers in particular to an office size about the same as the Slottsstaden office recently installed in Malmö City, Sweden. This office will have a capacity of over 20,000 numbers of which 10,000 were ready for service in 1951. The first 5,000 of these were cut over in February 1950. A view of this office is presented in Figure 1.

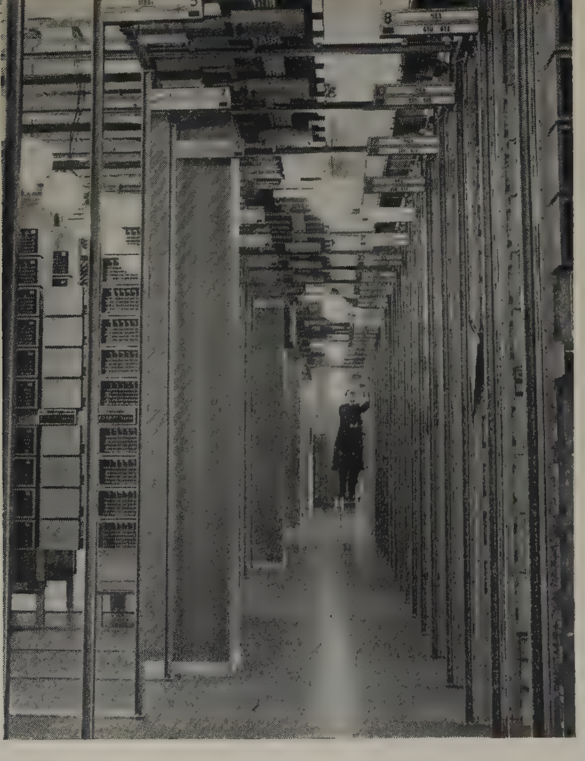

Figure 1. General view of the racks at Slottsstaden office in Malmö, Sweden

The crossbar switches and relays employed in this new system are the standard switches and relays used by the Swedish Telephone and Telegraph Administration in their various switching systems.[4] See Figures 2 and 3.

GROUP SELECTOR UNIT

IN THE DIRECT controlled crossbar system[1] each crossbar switch is used to carry only one connection at a time. A 100-point crossbar switch was used to reach one of 100 outputs. The outputs were multipled between switches as in the step-by-step system. Switches used in this manner with access to ten groups of ten outputs would require an average of 220 crosspoints per Erlang (36 unit calls) submitted. An average of 350 crosspoints per Erlang submitted would be required if 200 point switches with ten groups of 20 outputs were used. A feature of the new system is that the crossbar switches are used more efficiently in a link arrangement. An average of only 85 crosspoints per Erlang submitted is required.

In the direct controlled standard *41* system all the verticals of a crossbar switch were multipled together to give the

Full text of paper 51-321, "A New Common Control Crossbar Automatic Telephone System of the Swedish Telephone and Telegraph Administration," recommended by the AIEE Committee on Communication Switching Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions,* volume 70, 1951.

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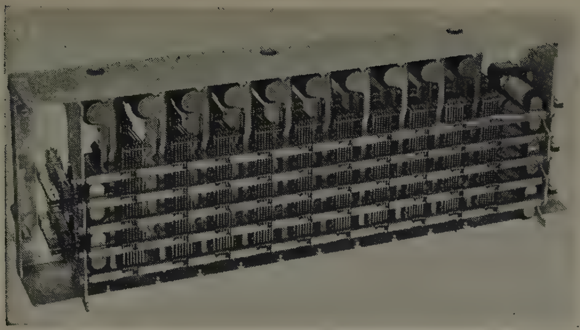

Figure 2. A modern Swedish crossbar switch

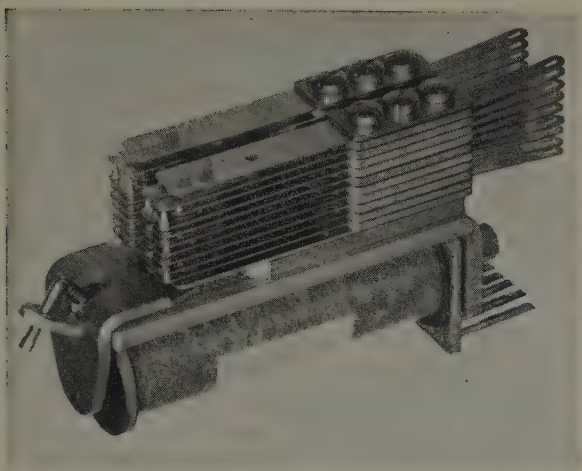

Figure 3. A modern Swedish general-purpose relay

switch a single input which could be connected to any of the 100 or 200 outputs. In the new common controlled link system each vertical unit is used as a separate 10-point switching device. Units of four 100-point crossbar switches are arranged in selector stages to give ten inputs access to ten groups of 20 outputs. Associated with each ten inputs is a common controller which serves to set up connection in the stage for one call at a time. As many as ten simultaneous connections may be established successively in each unit. Thus, traffic-wise, one unit acts like a shelf of ten 200-point step-by-step selectors.

Figure 4 shows a simplified diagram of the crossbar switch connections of a unit of ten selectors. This diagram is the same for each selector switching stage employed in the system. The squares 1 to 4 represent four crossbar switches, each provided with ten verticals which are indicated by the heavy lines. The crosspoints on crossbar switches 3 and 4 are individually wired and the individual crosspoints are indicated by heavy triangles. Switches 1 and 2 are multipled horizontally. Each horizontal level is indicated by a fine horizontal line crossing the heavy lines.

Ten junctors, *F1* to *F10*, arrive at crossbar switches 1 and 2. Each junctor is multipled to two crossbar switch verticals, one in crossbar switch 1 and one in crossbar switch 2. These verticals act together as a 20-point switching device. Thus switches 1 and 2 act as ten 20-point switches, one for each incoming junctor.

The crosspoints of these 20-point selectors are multipled horizontally and connected to 20 links *L1* to *L20*. Each link is connected to a vertical unit of crossbar switches 3 or 4. Each of the crosspoints of the verticals on switches 3 and 4 is connected to a junctor to the next stage. Thus each unit of selectors may reach a maximum of 200 outputs. These outputs are grouped so that the outputs connected to a single horizontal level form half of one group, the other half group coming from the corresponding horizontal level on the other switch. An example of an established connection through a group selector unit is indicated by heavy lines from junctor input *F1* over the closed crosspoint and crossbar switch 2 over link *L11* and through the operated crosspoint switch 4 to outlet 11 in group *DO*.

A call coming in over a junctor to a selector unit when the other nine junctors are idle can be connected to any one of the outputs in a group over one of 20 links. Each call makes busy one of the links, and when a call has been set up there are only 19 idle links for the next call so that in each of the other groups there is one outlet blocked in the selector unit. If nine calls are already set up in the unit a tenth call arriving over the remaining idle junctor can reach outlets only through one of the 11 idle links. In a selector switching stage provided with units of this type lower output usage

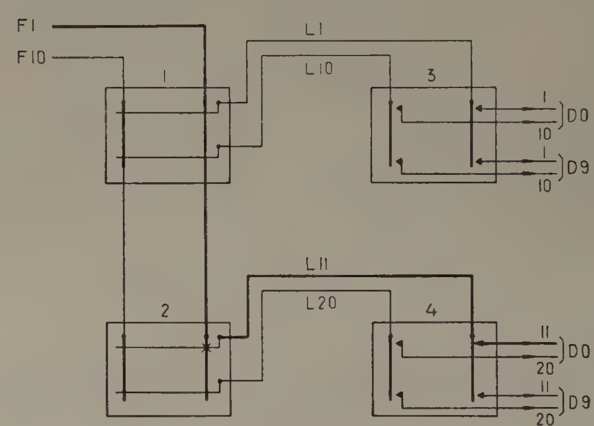

Figure 4. Simplified diagram of a selector

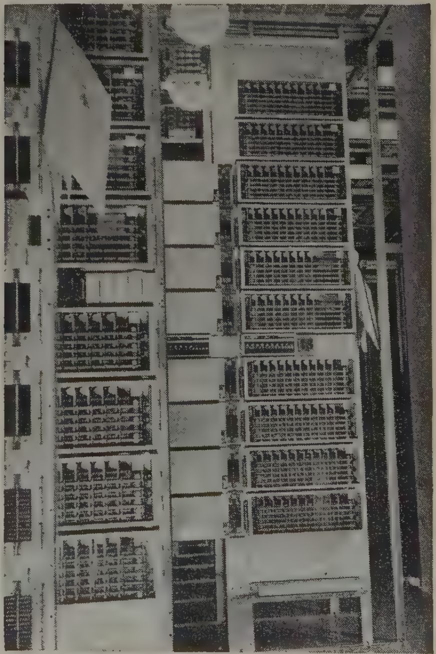

Figure 5. Racks of first selectors

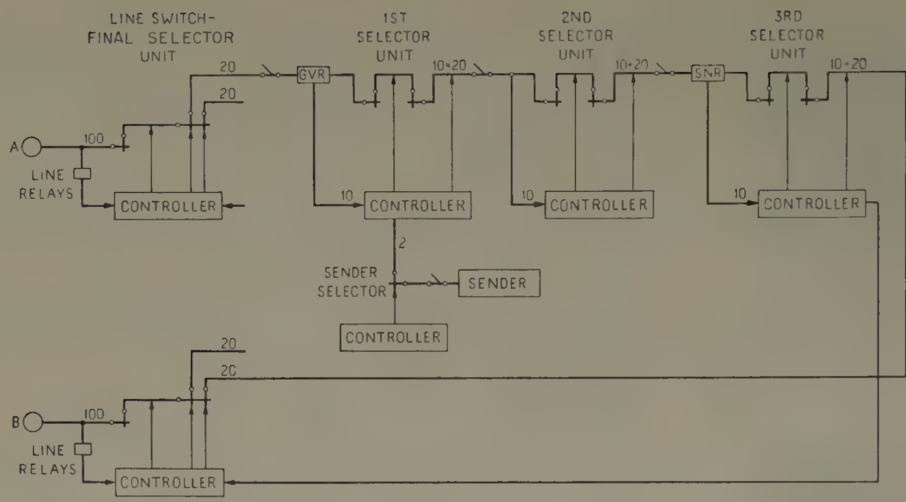

Figure 6. Internal route diagram of an office having a maximum capacity of 90,000 lines

is obtained than that ordinarily obtained by step-by-step selectors hunting over groups of 20 outputs but is higher than that obtained when step-by-step selectors hunt over groups of ten outputs. Figure 5 shows an illustration of a rack of first selectors including their common controller.

TRUNK DIAGRAM

The arrangement of the switching stages to form the new system is shown in outline form in Figure 6. The selecting system is made up on a decimal basis, four stages being provided for offices having a capacity of up to 90,000 numbers. The subscriber lines terminate in a combined line switch and final selector stage. Line appearances on switches in this stage are used for both originating and terminating calls.

The system of this size generally is provided with senders and the figure shows a simple crossbar sender link with its associated controller. The junctors incoming to the first selectors are connected to a relay unit *GVR*. These relays serve to supervise the originating end of each connection and to enable the call to be switched to the register during the dialing period. Junctors incoming to the last selector switching stage are connected to another group of relays which provide talking battery supply and ring the called line and provide busy tone on calls to busy lines. Besides the junctors between the last selector and the line switch-final selector switching stages there are separate operating circuits between the controllers for these stages.

The vertical units of the crossbar switch use four make contacts at each crosspoint except in the last selector units and in the line switch-final selector units where four or five contacts per crosspoint are used. Each crosspoint is used for only one possible connection.

Twenty junctors are outgoing from each line switch-final selector unit to the first selectors and 20 junctors are incoming to the unit from the last selector switching stage. The output junctors from several line switch-final selector units are multipled together to achieve a greater concentration of traffic. The junctors between each selector stage are multipled and distributing frames may be provided for grading this multiple. Junctors between the third selector switching stage and the line switch-final selector stage are not graded. Junctors from all third selector units which serve a certain hundreds numerical digit are directly connected to the proper line switch-final selector unit.

THE CIRCUIT OPERATION

Referring again to Figure 6, the following is a short description of the switching operations. When calling subscriber *A* removes his receiver from the switchhook his line relay is actuated and the origination of a call is noted by the line relay unit and in the controller for line switch-final selector unit on which his line appears. The controller recognizes the origination of a call and hunts for an idle junctor to a first selector stage which has an idle controller. When such a junctor has been found a connection is set up in the line switch-final selector stage to the junctor. Through the controller for the first selector a connection is established to a sender link. Each first selector controller has access to two links to a sender selector. The sender selector controller actuates its crossbar switch to hunt for an idle sender. Once the sender selector controller is connected a signal is sent back to the *GVR* relay unit associated with the first selector junctor. This signal causes the operation of a holding relay in the *GVR* unit and operates the cutoff relay associated with the calling line. Thereafter the controllers of the line switch-final selector stage and the first selector stage are released and the sender selector hunts for an idle sender. When an idle sender is found the connection is established between the line and the sender and the sender selector controller is released. The subscriber now can dial the desired number.

Two connections through a first selector controller to

Figure 7. A rack of senders. The covers of one sender are removed

senders may be established at any one time. Thereafter the first selector controller is made to look busy so that its junctors will not be chosen by the line switch-final selectors originating calls. Figure 7 shows an illustration of a rack of senders.

After sufficient digits are received by the sender it prepares to send (pulse) the information out to the various controllers to set up the call. The controller for the first selector stage through which the call is passed is called in again and the first numerical digit is pulsed to it. The first selector controller then tests to find an idle junctor associated with an idle controller to the desired second selector group. When such a junctor has been found, the connection is established through the first selector and the controller for the second selector is called in. The first selector controller then is released.

The second numerical digit is pulsed from the sender and received in the controller for the second selector. The second selector controller then hunts over the output junctors on its stage for an idle junctor associated with an idle controller to the desired group in the third selector stage. When such a junctor is found the second selector controller may be released after setting up the desired connection.

The last three digits of the number are now sent to and registered by the third selector controller after which the sender and sender selector are released. Using the hundreds digit the controller of the third selector is connected over operating circuits to the controller for the desired hundreds group line switch-final selector. If the desired line switch-final selector controller is busy the third selector controller waits its turn. When the controllers are connected together the last two digits of the subscriber's number, that is, the tens and units numerical digits, are transferred from the third selector controller to the line switch-final selector controller. The hunting for an idle junctor from the third selector unit and an idle link within the line switch-final selector unit takes place after which the two controllers establish the desired connections and release. Relay group *SNR* supplies talking battery to the connection after the controllers are released. Busy testing takes place in the *SNR* relay group and the connection to the desired subscriber's line is established with ringing current being sent out if the subscriber's line is idle. Busy tone is sent out from this relay group to the calling line if the subscriber's line is busy.

LINE SWITCH-FINAL SELECTOR UNIT

A SIMPLIFIED DIAGRAM of the connection of the switches in the line switch-final selector unit is shown in Figure 8. Units with their controllers are shown in Figure 9. The controller has been omitted in Figure 8 for the sake of simplicity. Squares 1 to 4 represent four crossbar switches, each provided with ten vertical units, indicated by heavy vertical lines. Each of the 100 lines multiples to one crosspoint on each of these four switches.

Squares *5A* and *5B* to *8A* and *8B* also represent four crossbar switches. Each of these crossbar switches has been divided into two parts to obtain a simplified representation. The crosspoints of the 40 vertical units on switches 5 to 8 are horizontally multipled to form 40 links, *L1* to *L40*. The verticals on these switches are divided into two groups:

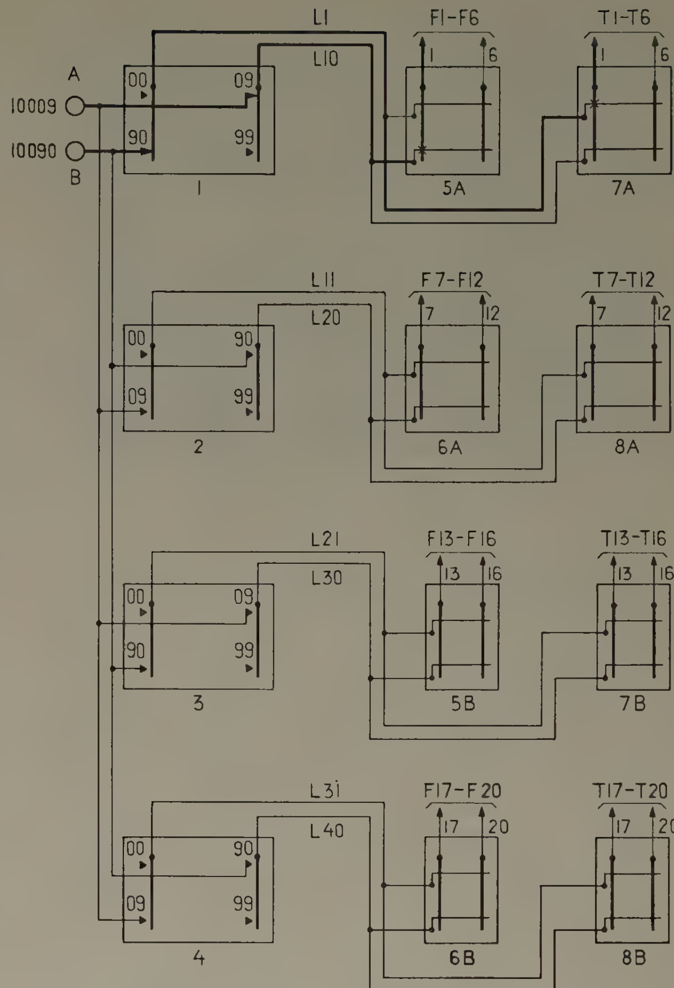

Figure 8. Simplified diagram of a line switch-final selector

20 output junctors, *F1* to *F20*, and 20 input junctors, *T1* to *T20*. The links are used for either originating or terminating calls since they multiple before both the incoming and outgoing junctors.

Connection can be obtained over each link *L1* to *L40* to any of ten subscriber numbers, and connection can be obtained to all 100 subscriber numbers over the ten links connected to any one of the crossbar switches 1 to 4 which can be said to form a group of links. There are four such groups of links connected respectively to crossbar switches 1 to 4 and to parts of crossbar switches *5A* and *7A*, *6A* and *8A*, *5B* and *7B*, and *6A* and *8B*. Each of the first two groups of links, *L1* to *L10* and *L11* to *L20*, appear before 12 crossbar switch verticals, six incoming and six outgoing. The last two groups of links, *L21* to *L30* and *L31* to *L40*, appear before eight verticals each, four incoming and four outgoing.

Before a connection is established in the line switch-final selector unit, hunting takes place for idle links within the unit and idle junctors to the first selector or from the third selector. This hunting is in a fixed order beginning in the first group of links, then going to the second, third, and fourth link groups in order. To carry the highest possible traffic load, the groups of links chosen first are provided with a greater number of outgoing junctors and incoming junctors than groups of links chosen later. The junctors to the first selectors are graded together with corresponding junc-

tors from other line switch-final selector units so that ten line switch-final selector units comprising 1,000 subscriber numbers normally are provided with 50 to 70 junctors to first selectors. The 20 incoming junctors from the third selector units are directly connected to the group outputs of all the third selector units in the same thousands numerical group.

The subscriber numbers are associated with the crosspoints of these crossbar switches as indicated in Figure 8 by numbers at the crosspoints (00 to 99). The lines are connected in crossbar switches 1 and 3 in such a manner that those having the same units digit are connected to the crosspoint multiple of a certain vertical unit. The lines are further connected to crossbar switches 2 and 4 in such a manner that lines having the same tens digit are connected to the crosspoint multiple in a certain vertical unit.

The sequence of selection for each call takes place in such a manner that a link wired to a vertical unit for a units digit is selected alternately with a link connected to a vertical unit for the tens digit. The manner of connection of subscriber lines in the line switch-final selector unit thus forms a pattern whereby a grading, here called "alternate sequence grading," is obtained. The alternate sequence grading decreases the chance of blocking calls because within certain limits it is probable that traffic is distributed by chance to the verticals which are successively selected. There is a gain in this arrangement, in spite of the small amount of material used, because, for the permitted congestion, the traffic density through the line switch-final selector unit can be relatively high, and because those particular subscriber lines will hardly be subjected to abnormally high congestion with a number of by chance unsuitably placed high-duty subscriber lines.

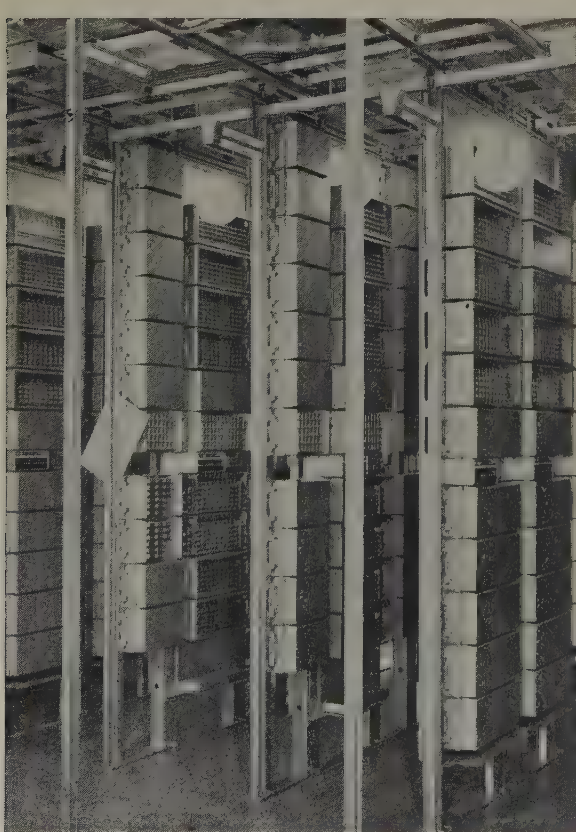

Figure 9. Racks of line switch-final selectors

A method has been furnished for calculating the necessary number of switching elements needed for handling a certain volume of traffic with a given number of lost calls in the new link system.[5,6] Congestion of traffic in the line switch-final selector unit when subscriber lines of heavy traffic are by chance connected to such a unit has also been studied.[7] The line switch-final selector unit is engineered on the basis of a normal load of 6.7 Erlangs (240 unit calls) with one call lost for every 500 handled ($P=0.002$), but an amount of traffic of about 10 to 12 Erlangs can in fact be reached at this loss.

In Figure 8 heavy lines indicate talking paths set up in the line switch-final selector unit, one for an incoming and one for an outgoing call. The outgoing call originates at subscriber *A* over a vertical unit crossbar switch 1 through link *L10* and over an operated crosspoint in crossbar switch 5*A* to junctor *F1*. The incoming call is shown arriving over junctor *T1* through a crosspoint on crossbar switch 7 and over link *L10* through crossbar switch 1 to subscriber *B*.

When a line such as *A* originates a call its line relay in the *LR* unit is operated. If the controller associated with this line switch-final selector unit is idle, the line's tens and units digit, 0 and 9, are indicated by the line relay circuits. From these circuits the proper select bars on each of the crossbar switches 1 to 4 and 5*A* to 8*B* are operated and the four links *L10*, *L11*, *L30*, and *L31* which can be used to connect the subscriber's line to a junctor are tested. The operation of a relay for each group with idle links connects the test wires for the outgoing junctors to the controller which starts the testing operation. When an idle junctor is found, for example *F1*, the connection is set up by the operation of the magnet connected with junctor *F1* and thereafter the magnet connected with link *L10* on switch 1 operates. A call start signal then is transmitted to the controller of the first selector associated with this junctor and thereafter this controller is dismissed when the cutoff relay of the subscriber's line circuit is operated.

Testing of idle links suitable for incoming calls takes place in substantially the same manner as for outgoing calls. A call from the third selector is preceded by testing to determine if the controller for the desired line switch-final selector unit is idle. Only one third selector unit may obtain access to the line switch-final selector unit at a time. Precedence is obtained by means of a lockout circuit.

After the line switch-final selector controller is seized, the tens and units digits are transmitted from the third group of selector controller units. The tens and units numerical digits of the called subscriber are used in the line switch-final selector unit to operate the proper select magnets of the switches. Four links, for example *L1*, *L20*, *L21*, and *L40*, are the only ones which can be used to establish a connection to line *B*. The links are tested successively as before and if in this case *L1* tests idle, idle indications are sent to the third selector controller for those of junctors *T1* to *T6* that are idle. When an idle junctor has been found by the third selector controller the connection is established in the third selector and the line switch-final selector unit proceeds to set up the call from this junctor to the called line. The

hold magnets associated with junctor $T1$ and link $L1$ are operated and the connection is established from the *SNR* relay circuit to the desired subscriber *B*. The controllers are released after the connection has been set up. Busy test is made by the *SNR* relay circuit which remains as a part of the established connection.

GROUP SELECTOR CONTROLLER

The controllers of the different selector switching stages shown in Figure 6 are not entirely alike, but all controllers contain a crossbar switch connecting the incoming junctors to the respective controllers and progressively hunting for idle output junctors and relays for receiving numerical pulses. The controller for the line switch-final selector stage does not contain a crossbar switch, it being comprised of nothing but relays.

Switching operations are of the simplest kind in the second selector unit. Thus a junctor from the first selector unit is connected to a pulse receiving relay unit in the second selector controller over a vertical of the crossbar switch in the controller. Relays are provided in the controller for receiving numerical pulses over the tip and ring wires and a third wire of the junctor from the sender through the previously set stages. When the numerical pulses have been received, hunting is started for an idle link which has access to an idle junctor to the next stage in the desired group. When an idle junctor has been found the connection is established and the controller in the next stage is called in. When the controller in the next stage is connected a signal is sent back over the junctor to the controller in the second selector stage. As soon as this signal has been received the second selector controller is released. As long as the second selector controller is busy the other idle junctors to this unit cannot be called since they are made busy artificially.

The controllers of the other switching stages perform other functions in addition to the principal one just described. The controller for the first selector has access to two different sender selectors. Two calls can be connected simultaneously through the controller to senders. When the sender is ready to set up a connection the pulse receiving relays in the first selector controller are connected to the path from the sender during the time needed for operation of the first selectors.

As mentioned earlier the controller for the third selector receives three numerical digits. The tens and units digits are passed over 20 wires directly to the select magnets of the final selectors over a hundred group connector in the third selector controller. This connector is operated in accordance with the hundreds numerical digit to pick the required line switch-final selector unit.

PULSE METHODS AND SUPERVISION

Two types of controllers have been designed for the selector units, one receiving dial pulse and another for code pulsing. (Code pulsing is much like the panel call indicator pulsing used in the panel and crossbar systems in the United States.)

The new common control link system can, without the addition of senders, interconnect with other systems where the selections may be made by dial pulses. Within larger

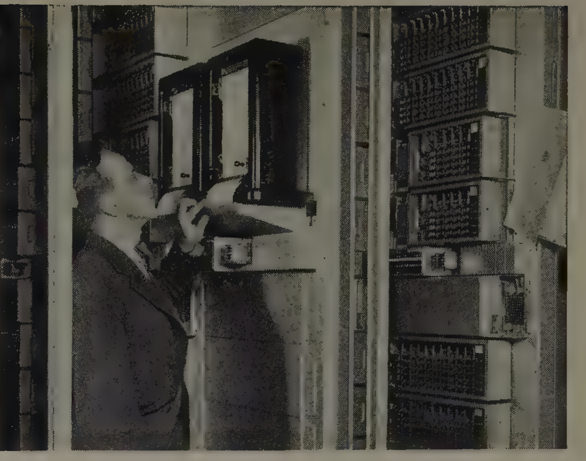

Figure 10. A trouble recorder for recording out-of-order conditions

offices of this system code pulsing is used with senders whereby connections are set up more rapidly. Small rural offices employ controllers which receive dial pulse directly and therefore need no senders. In such systems the selector controllers are still common to ten input junctors.

To reduce maintenance effort and maintenance cost many self-checking and trouble-detecting features are included in the controllers. Thus, before a controller is released, it assures itself that the controller in the succeeding switching stage has received the call correctly. If trouble does occur the first controller engages a trouble recorder, and a record is made. The trouble recorder will record automatically a succession of troubles on a paper tape. Figure 10 shows a trouble recorder. It is expected that the cost of maintenance of the new common control system will be substantially less than that for the previous direct control system because the new system has very simple circuits, very few marginal adjusting requirements of relays, and the ease of locating trouble due to the availability of the trouble recorder.

Although economically suitable for large size offices, this new system is particularly well adapted for plants which need decentralization of offices because, according to experiences in Sweden, crossbar offices can be left unattended for long periods of time without any inconvenience.[8,9]

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Resistance Effect on 230-Kv Faults at Grand Coulee

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EARLY STUDIES and calculations[1,2] concerning the bussing at 230 kv of the generators at the Grand Coulee Power Plant and the lines emanating therefrom indicated that the asymmetrical fault currents to be encountered as the Coulee installation grew would increase very rapidly and the development of ultrahigh interrupting-capacity circuit breakers, as well as means of limiting the fault current, were investigated thoroughly.

An investigation was made to determine the possibility of using resistance in the two river-crossing circuits interconnecting the two Coulee switchyards to reduce the asymmetrical portion of the total fault current. This included resistance tests to verify the basis of computation of the effect that resistance would have on the fault current. The tests also provided a means of checking the calculated value of resistance required to limit the fault current at circuit-breaker interruption to the desired value.

The tests pertained directly to the effect that added resistance has on the resultant fault current as its transient d-c component is effected, thereby reducing the fault current that the circuit breakers would be interrupting. The interrupting duty rating of a circuit breaker is determined at the point of contact parting and the current rating at the first half-cycle of arcing. Therefore, the fault current that a circuit breaker is required to carry momentarily and prior to "contact parting" normally will be considerably greater than the rated current value of the circuit breaker.[3]

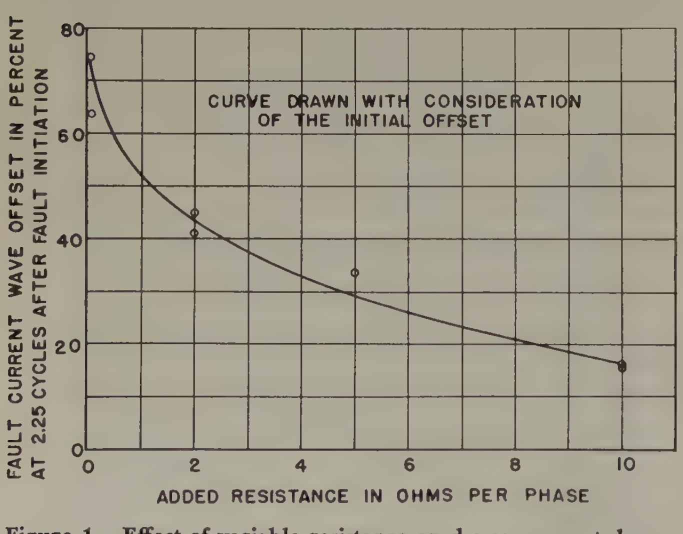

Figure 1. Effect of variable resistance on d-c component decay. Points obtained from phase currents with initial offset near 100 per cent

The tests were made with one generator, a small section of transmission line, and a variable resistance with the object of simulating as nearly as possible equivalent conditions that would actually exist with a bus fault with resistance in the bus and the ultimate generator installation.

The rate of decay in the d-c component was affected greatly by the variable resistance added at the point of fault through the effect of this resistance on the machine's armature constants.

This effect is shown in the expression[4]

$$T_a = \frac{X_2 + X_{\text{ext}}}{2(r_a + r_{\text{ext}})} \text{ in seconds}$$

where the external reactance (X_{ext}) is added to the negative-sequence reactance X_2 of the machine and the external resistance (r_{ext}) is added to the armature resistance of the machine (r_a) to obtain the armature time constant (T_a). The external reactance of the test circuit was low and introduced little change for the combined reactance and can be disregarded. However, it is ascertained readily that the added resistance results in an appreciable change in the time constant which is confirmed by the oscillographic results and the calculated values, as shown in Figure 1.

The relaying time and circuit-breaker contact parting time at Coulee total about 2.25 cycles. The tests with the faults at the tower show a d-c component decay after 2.25 cycles of fault current of approximately 30, 57, 65, and 84 per cent respectively for added resistance of 0, 2, 5, and 10 ohms per phase. This relation confirms the expected reduction in the fault-current value at circuit-breaker interruption and would reduce very appreciably the required asymmetrical rating of circuit breakers on the Coulee bus. On this basis, bus resistors could be utilized that would reduce satisfactorily the asymmetrical fault that the circuit breakers would be required to interrupt to a value within the present circuit-breaker ratings. However, it was found that the characteristics of the copper alloy conductor would prevent its usage in this instance in that the conductor temperature would be prohibitive under heavy load conditions and the presently installed 10,000,-000-kva circuit breakers are considered adequate for the Grand Coulee Power Plant.

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Optimum Synthesis of 3-Phase Reluctance Motors

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USUALLY THE MOST significant problem encountered by a reluctance-motor designer is to obtain a motor which will satisfy a prescribed pull-out torque and at the same time pull in a specified load torque and load inertia. He also is faced with the situation that different sizes of stator laminations which he would like to use are already available. With a maximum flux density in the stator teeth and maximum current density in the stator conductors, the designer then would want to obtain systematically for each available size of stator laminations the solution for the following quantities which would constitute the optimum synthesis of the reluctance motor: 1. the ratio of minimum to maximum equivalent air gap, which is actually a measure of the geometry of the machine; 2. the equivalent length of stack; 3. the rotor resistance which, together with the desired starting torque, would make the choice of the number, size, and shape of rotor bars possible; 4. the minimum equivalent air gap; and 5. the number of stator conductors.

Such a systematic synthesis procedure now is possible

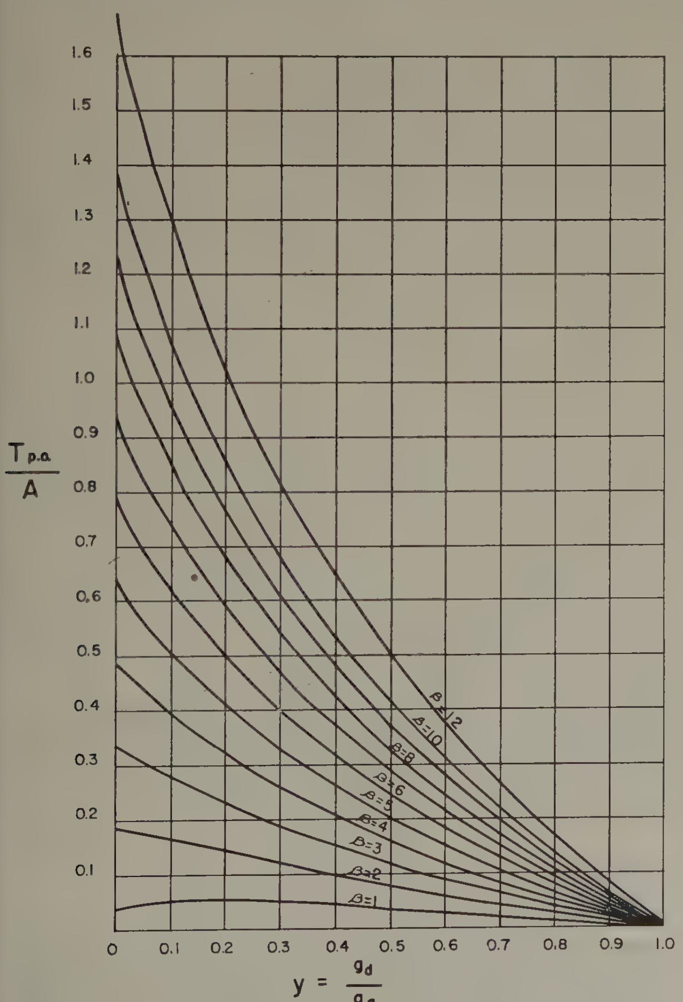

Figure 1. Pull-out torque family of curves

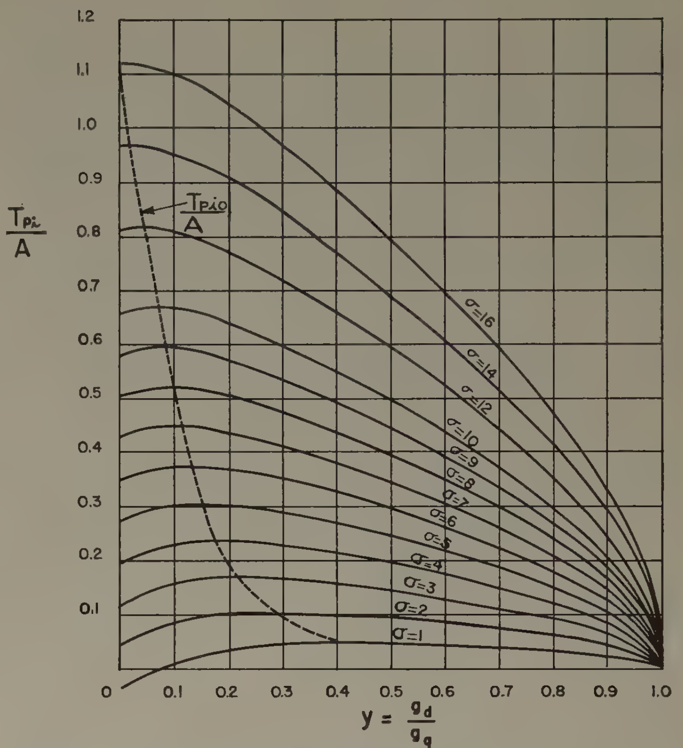

Figure 2. Pull-in torque family of curves. Dotted line is the universal curve of optimum pull-in torque

through the use of the two families of curves shown in Figures 1 and 2. These were obtained by the transformation of analysis equations of the reluctance motor to their synthesis forms in terms of the dimensions of the motor and physical constants. The analysis equations are based on the extension of the 2-reaction theory of synchronous machines to include the nonexcited case and an intensive differential analyzer study which led to the pull-in criterion for reluctance motors for the first time. This criterion was verified both qualitatively and quantitatively.

The method is based on a stator magnetic circuit of fixed contour, a stator lamination of certain size. To accomplish the prescribed performance of the motor, and also arrive at a reasonable length of stack, value of rotor resistance, and ratio of minimum to maximum equivalent air gaps, it is necessary to select the right lamination size for the prescribed performance. A minimum limit on the rotor resistance is set by the requirement that the electric starting torque developed by the motor must be greater than the specified load torque to be pulled in.

Digest of paper 51-361, "Steady-State and Transient Synthesis of 3-Phase Reluctance Motors (Synchronous Motors without Field Excitation)," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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This article is a condensation of the author's doctorate degree thesis which was presented at the University of Pennsylvania in February 1951.

Recent Deep-Bar Induction Motor Developments

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DEEP-BAR induction motors have rotor slots approximately one inch deep. Their excellent starting characteristics are due to skin effect. Since skin effect in copper at 60 cycles is approximately 0.4 inch, the copper losses and starting torque are as if the current were confined to a layer 0.4 inch deep. Thus, the rotor resistance of these motors is 2.5 or more times as great when starting as when running. These motors develop 150 per cent or more starting torque and are useful as a general purpose motor.

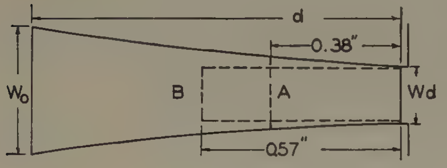

Figure 1. Graphic representation of skin effect in a tapered bar; (A) resistance, (B) reactance

The older motors of this type had rectangular bars; the newer types of bar are wider at the bottom of the slot than at the slot opening. While made in different forms, generally they develop as much as 175 per cent torque at starting. The theory for these bars has lagged behind practise, and the author has developed several methods for computing the performance of induction motors with these bars.

One of the types of bar is tapered, such as is shown in Figure 1. The results may be stated briefly and approximately: 1. the running resistance depends on the area of the bar; 2. the running reactance is as if the bar were rectangular with a width equal to the slot opening and a depth equal to the whole slot; 3. the starting resistance is the same as that of the trapezoid *A* in Figure 1, which is 0.38 inch deep; 4. the starting reactance is the same as that with a uniform current distribution in the rectangle *B* which is 0.57 inch deep. Figures are available for materials other than copper.

One of the types of bar used has a circular lower part and a rectangular upper part. Many books give the slot constant for a circular slot as 0.62; we find that under running conditions the slot constant is 0.72. There is a graphical method for finding the starting constants of this slot.

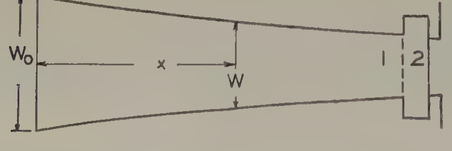

Figure 2. Compound tapered bar with an enlarged slot opening

One type of bar studied is shown in Figure 2. It differs from the bars in use by having an enlarged portion near the slot opening. A numerical calculation indicates that this type of bar should have even better starting performance than bars in current use.

Deep-bar motors are all termed low inrush motors. Generally they take only 5.5 times the current of a perfect motor. A 3-phase 440-volt motor of this type will take as little as 5.5 amperes per horsepower at starting.

The mathematical methods which were used to obtain the results given are an extension of those used by A. B. Field in his classic article published in 1905.[1] Field succeeded in integrating current and voltage for a rectangular bar in a rectangular slot. We have introduced an exponential factor in the expression for the slot width, and the mathematics have been shortened by integrating the impedance or admittance instead of voltage and current. This was done for both a simple and a compound bar.

Graphical methods of integration have been used in the past but less often for a complex variable. Vector integration by a graphical method has been done for voltage and current, but the process can be shortened by integrating a single variable, namely, impedance (or admittance). Thus, the bar is divided in a number of layers and each layer is combined with all between it and the bottom of the slot.

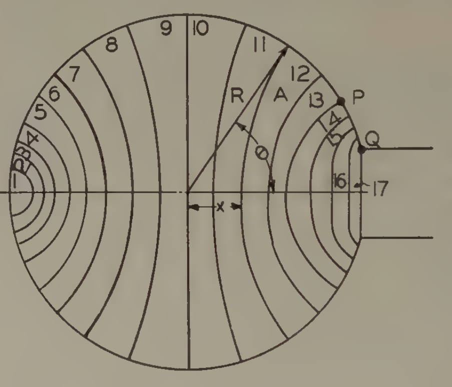

Figure 3. Circular bar divided into zones of equal permeance

The graphical process becomes more difficult when the magnetic lines of force are of curved shape. This difficulty is resolved by making a test with a water trough model, and mapping the shape of the lines of force. Then the conductance and the reactance of each layer may be calculated. Such a field map is shown in Figure 3 by means of which the properties of a round slot were found.

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Detection of Slot Surface Discharges in High-Voltage Machine Stator Windings

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Basic studies of the nature and method of detecting slot discharge phenomena in high-voltage stator windings show that the discharge is a result of loss of electric contact between conducting coil surfaces in the slot and the core. Several methods were studied for detecting and locating such discharges and the development of a slot discharge analyzer is described.

THE PHENOMENON OF surface discharging between conducting coil surfaces and core has been observed on several high-voltage stator windings in the past 5 years. This phenomenon is distinctly different from surface corona which may be present in high-voltage end windings or internal void ionizations which exist to a greater or less extent in the internal structure of high-voltage machine insulation. There are several cases on record where surface discharging in time has led to serious degradation and eventual failure of the stator coil ground insulation.

It is the purpose of this article to describe the nature of the basic phenomena and to report studies in connection with the development of detection equipment. It is important to detect discharging if it exists during routine generator maintenance inspections because corrective measures, if made in time, are usually simple, inexpensive, and not time-consuming. The discharge analyzer described in this article has been used extensively in connection with the generator maintenance inspection program of the manufacturer. It is a relatively simple test requiring only a source of a-c test voltage of sufficient capacity to charge the stator winding under test to its normal operating voltage stress.

BASIC PHENOMENA

MODERN PRACTICE in connection with the insulation of high-voltage stator windings includes the use of a conducting surface coating on the slot portions of the stator coil insulation. This conducting material is applied to the coil finish tape which may be either of Fiberglas or some other inorganic textile. The intended function of the conducting surface treatment is to relieve the voltage stress on unavoidable air gaps which exist between the coil surface and core. Without coil surface conducting treatments these gaps ionize at normal operating voltages with resultant corona formation in the gaps which is generally undesirable.

Insulated coils are built slightly smaller than the finished slot size. As coils are wound into the stator, mica plate (usually in the range of 0.020 to 0.030 inch thick) is driven down one side of the coil. This coil-tightening operation makes for a tighter coil fit than would be possible otherwise and forces the other coil side into good contact with the slot. This construction is believed to be advantageous in that coils may be wound with less likelihood of damage and a better mechanical fit in the slot is assured. However, it does place the entire burden of draining the coil-charging current on the bottom and one side face in the case of bottom coil sides. Where an insulating filler strip between top and bottom coil sides is used the entire charging current of the top coil side must be handled by one side face.

If for any reason electric contact is completely lost between the conducting coil surfaces and core, a seriously destructive capacitive discharge results. For coil surface resistivities which are less than several hundred thousand ohms per unit area no discharge is possible if the resistive coating is continuous and the coil surface makes contact at any point along the length of the slot. Complete loss of electric contact with the core is necessary in order to give rise to a surface discharge.

The frequency of occurrence of this phenomenon has been low. The first case of difficulty was reported after 17 years of trouble-free experience since the introduction of conducting coil finishes. The first such experience naturally brings on a re-examination of insulation practices with the objective of preventing similar occurrences on future designs. Design and manufacturing changes result which take care of the future. In this case a conducting coil filler strip was developed for use between top and bottom coil sides. This provides an additional grounding path for top coil sides. No difficulty has been encountered due to discharges on bottom coil sides. Other changes included the development of a new varnish-type conducting compound and improved methods of applying the surface treatment.

Also developed were improved methods for checking uniformity of coil-tightening operations. As a final step in this problem detection equipment was developed which made it possible to make a rather simple test on ma-

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Essentially full text of paper 51-367, "Slot Discharge Detection Between Coil Surfaces and Core of High-Voltage Stator Windings," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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chines in service to determine the adequacy of the coil surface grounding.

In the few cases where surface discharging has been found by this test, corrective measures needed to suppress the discharge have been minor in scope. Uncorrected, this phenomenon in time can be severely destructive to the major coil insulation.

DISCHARGE ANALYZER THEORY

Detection of discharges which result from partial breakdown in nonhomogeneous dielectric materials (such as the combination of gaseous voids in a solid dielectric) is possible because of electric oscillations which result in the circuit comprising the materials under stress and the voltage source.

In the case of high-voltage machine insulation, voids normally exist within the internal structure of the insulation. For slot discharge detection purposes, it is therefore necessary to distinguish between electric oscillations which result from internal voids and those which result from the surface discharge. The oscillations resulting from these two phenomena would be expected to be distinguishable, because the discharge energies involved are of an entirely different order of magnitude. In the case of the slot discharge, the energy would be that resulting from all or a substantial part of the entire coil side capacitance. In the case of the internal voids only the capacitance of an extremely small area would be involved. The energy in the discharge varies as the square of the voltage across the gap and directly as the effective capacitance at the point of breakdown.

Electric oscillations which result from the gaseous voids in solid insulation are detectable over a wide range of frequencies. Tykociner, Paine, and Brown[1] report the results of extensive studies on ionization detection in cable insulation. For cables with ionizable voids, they report that oscillations resulting from ionization of this type have two components as follows:

1. Oscillations in the audio-frequency range which follow the successive breakdown and build-up of voltage across the voids or air gap. These have the nature of a wave train which is repetitive with alternations of the applied voltage. The frequency and amplitude of these are stated to be principally a function of void size and chemical and physical factors.

2. Superimposed on the audio-frequency oscillations are damped oscillations in the radio-frequency range. The frequency and magnitude of this component are reported to depend principally on the constants of the test circuit.

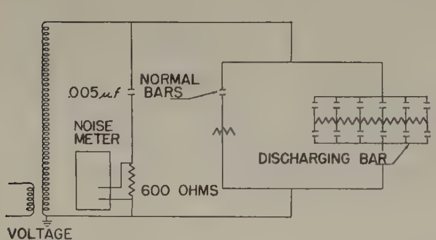

Figure 1. Connections for conducted radio noise measurements

In the development of the discharge detector the relative discriminations between surface discharging and internal void ionization were studied with both radio- and audio-frequency detection schemes. It was found that the relative discrimination was inherently better at audio-frequencies. It was further found that in the audio-frequency range internal ionization and surface discharging had maximum energies at different frequency ranges. Accordingly, the use of a circuit resonant in the frequency range where energy from surface discharging was high resulted in correspondingly poor sensitivity to oscillations resulting from internal ionization.

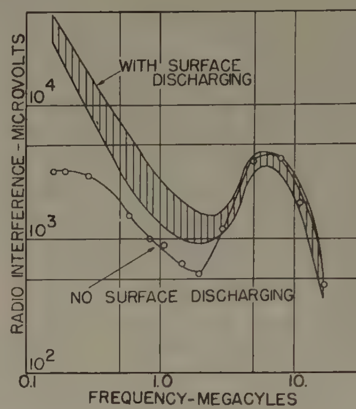

Figure 2. Noise-frequency characteristic, radio-frequency measurements

TESTS

Tests were made in the laboratory using test bars wound into a core model. It was possible in these tests to make a comprehensive study of the merits of the several detection schemes. Test bars were prepared having low, medium, and high surface resistivity. Some were prepared with poor fill and others with good fill of conducting material in the coil binder tape. Bars were wound into the model according to standard practice except that their tightness in the slot was varied. Bars were studied which were tight, loose, and clear of the slot wall on the contact face.

It was found that when there was an air gap between coil surface and slot wall discharging would occur. When the gap was 0.010 inch discharging occurred at test voltages as low as 3 kv.

Since it was possible to produce or eliminate discharging at will by the removal or application of a ground at one point on the coil surfaces, all the bars were finally wound in the core with slot mica on one side and an air gap of approximately 0.010 inch on the contact side. Foil electrodes to which a ground could be applied were wrapped around the bar, just outside of the core. As a further refinement, a micrometer gap was connected from the grounding foil to core. With this gap, the effect of very small gaps between the test bar surfaces and coil could be studied. Also in studying the frequency sensitivity of the various audio-frequency circuits under consideration a continuous frequency voltage from an audio-oscillator

was impressed across this gap instead of an actual discharge. This simulated discharge voltage was more controllable than the actual discharge and consequently facilitated the evaluation of the characteristics of the circuits investigated.

RADIO-FREQUENCY STUDIES

A STANDARD RADIO noise meter was used for all tests in the radio-frequency range. The instrument has high sensitivity, indicating values as low as 1 microvolt when used as a voltmeter or 1 microvolt per meter when measuring field strength. The noise meter was used in two ways:

Loop Antenna. By using the noise meter with a special type of loop antenna the field generated by discharges within the machine can be detected and measured. An elongated loop was designed which could be inserted in the air gap and positioned over the slots of the stator windings. The intent of this method was to survey the stator coils of a wound machine without having to make a direct physical contact with the conducting surface of the coil.

Conducted Noise Measurements. Conducted noise measurements were made by coupling the noise meter directly to the high-voltage line. As shown in Figure 1, a 0.005-microfarad capacitor with a 600-ohm resistance in series on the ground side was connected directly across the high-voltage line. The noise meter was used to measure the high-frequency drop across the resistor.

With either of these methods, it was found that the energy of the field due to ionization of voids within the insulation was picked up as well as the surface discharges. The curve of Figure 2 shows the variation of conducted noise measured at frequencies from 0.16 to 18 megacycles of low surface resistance bar in the core model. The

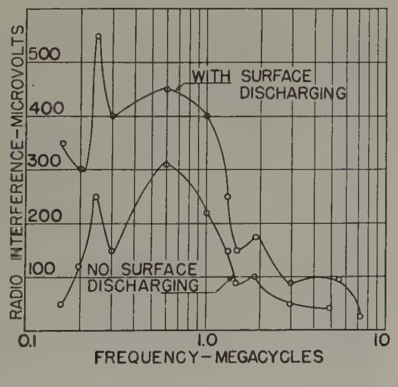

Figure 3. Noise-frequency characteristic, radio-frequency loop antenna measurements

lower curve is for a test bar well tightened in the slot and the upper envelope is for the same bar loose and discharging to core. For bars having higher surface resistance there was correspondingly less difference in measured noise between the arcing and grounded conditions at any frequency. Even with the low surface resistance bar, at frequencies above 3 megacycles, the ionization of internal voids completely masks the surface discharging. As shown at 160 kc (the lowest frequency at which radio noise measurements could be made with available equipment), the measured noise under arcing conditions is approximately 10 to 20 times greater than that measured when the bar is not discharging.

With the elongated loop antenna placed above the slot containing a test bar, similar measurements over the frequency range were made. The field picked up in this manner is a combination of the radiated magnetic and electrostatic fields due to the radio-frequency currents within and at the test bar surface. Results similar to the conducted measurements of Figure 2 were obtained using the loop pickup for low surface resistance test bars. Figure 3 illustrates the noise-frequency characteristic determined with loop antenna pickup. As was true for the conducted measurements bars with surface resistivities of the order of 100,000 ohms per square or higher showed only small differences in noise when measured "arcing" and well grounded.

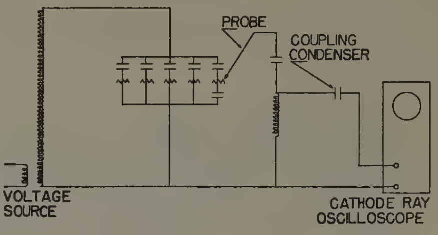

Figure 4. Connections for audio-frequency probe measurements

AUDIO-FREQUENCY CIRCUITS

Probe Measurement. Slot discharging was found to be most readily detectable with a circuit involving the use of a probe which was made to contact the conducting surface of the coil sides. Figure 4 is a schematic diagram of the circuit used. As shown, the pickup circuit consists of a probe, a capacitor, and an inductance. All are connected in series and one side of the inductance is grounded. Connected across the inductance are the input terminals of a high-pass filter (used for blocking 60-cycle voltage). A conventional cathode-ray oscilloscope is connected across the output terminals of the filter. With the circuit constants used, the pickup circuit is in series resonance at 2,000 cycles. The 60-cycle impedance of the pickup circuit is 1.3 megohms. The selection of a suitable value of capacitance for the series capacitor is determined by two considerations:

1. Values of capacitance as small as 0.00005 microfarad (corresponding to series resonant frequency of 10,000 cycles) had adequate sensitivity for detecting discharges in the model set up. However, the sensitivity increased with increasing value of series capacitance in the probe.

2. Capacitance values greater than 0.005 microfarad (corresponding to a resonant frequency of 1,000 cycles) reduced the 60-cycle impedance of the pickup circuit to the point where it tended to suppress the discharging.

To check a machine for slot discharging by this method, it is necessary to contact the conducting coating of the individual coil sides of the machine. This usually involves

removing end bell covers to get to the winding. It also involves the use of a suitable probe. Conducting areas within the slot are accessible at the vent ducts. On the machines tested to date, it has been possible to contact the coil surface at vent ducts near the top of the winding. In general, only top coil sides of a machine are accessible.

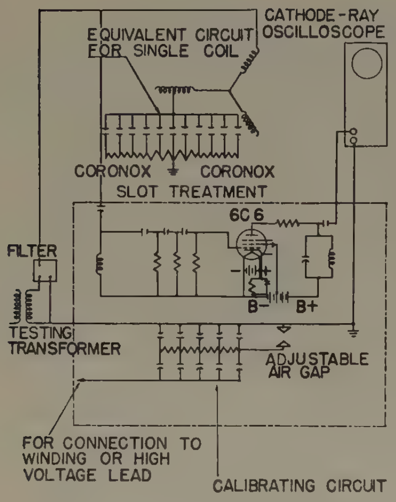

Figure 5. Schematic of the slot discharge analyzer showing connections for making over-all tests on a generator stator winding

This is probably not a serious limitation of this method since no evidence of discharging has been found on bottom coil sides.

Complete Winding Measurements. Figure 5 shows the circuit used for detection of slot discharging in which test connections are made to the machine terminals. In this case, the constants of the pickup circuit are the same as for the probe method. The capacitor, instead of being connected to a probe, is connected to a machine terminal. As shown, a stage of amplification with a tuned parallel resonant plate circuit is inserted between the output terminals of the 60-cycle filter and the input to the oscilloscope. The plate circuit is tuned to the same frequency (2,000 cycles) as the pickup circuit. This additional filtering improves the relative sensitivity between surface discharging and internal ionization.

The detection of surface discharges by coupling through capacitance to machine terminals is more difficult because the detectable discharge voltage is reduced in the ratio of the coils which are discharging to those which are in good contact. In the case of a generator with one coil side out of 800 discharging, the detectable discharge voltage at the machine terminals is reduced by 800 times. It is therefore necessary to provide more amplification to detect the discharge voltage. Also amplified are the higher frequency oscillations produced by internal ionization of all the coil sides in the winding. The use of the amplifier with tuned plate circuit provides the necessary increased selectivity. Also shown in Figure 5 is a calibrating circuit. The circuit is a capacitance-resistance network which simulates a coil side in a slot. With this circuit a discharge can be produced which simulates a coil side discharging in a slot. The calibrating circuit is connected in parallel with the winding under test. The gain of the oscilloscope is adjusted so that when the calibrating circuit is discharging the magnitude of the disturbance trace on the screen is several inches. If the disturbance trace substantially disappears when the discharge from the calibrating circuit is stopped it is concluded that no coil sides in the machine are discharging.

TEST EXPERIENCE

When used for complete winding checks the analyzer is limited in the following respects:

1. The discharge voltage at the machine terminals in general is a fraction of a volt. Considering that the applied voltage is of the order of 8 kv it is apparent that the disturbance voltage is a small percentage of the applied voltage. The presence of high harmonics in the test source which limit the sensitivity of the device is possible. This effect can be minimized by the use of a suitable line filter.

2. While it is possible to build a filter which is effective for steady-state disturbances, it is very difficult to filter out high-frequency transient disturbances which arise in connection with the operation of bell alarms, welders, and so forth. It therefore is essential to ascertain whether the disturbance voltage is originating in the machine under test. One possible check in this connection is to substitute a high-voltage capacitor for the machine under test and observe change in disturbance, if any.

3. Some discharges have been observed which were found to be of an intermittent nature. It is therefore necessary to make several observations of reasonably long duration.

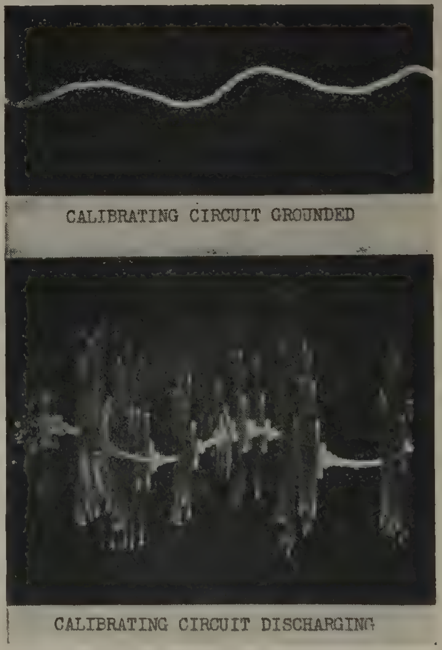

Figure 6. Results of a slot discharge detection test on a turbine-generator stator. Test voltage, 8 kv

Techniques and equipment have been developed which have overcome these limitations. Complete winding tests give dependable indication of the presence or absence of discharge phenomena. Probe tests should be necessary only for location of affected coil sides when the complete

winding test indicates the presence of discharging. An improved line filter has been developed and has proved satisfactory. In making tests in the field it has been found that local conditions vary and are somewhat unpredictable. Also it is not always practical or necessary to isolate completely the winding under test. In making field tests, when disturbance voltage is detected, check measurements should be made to establish definitely that the machine insulation is responsible for the disturbance. It has been found helpful in this connection to substitute a high-voltage capacitor (0.5 microfarad) for the machine insulation under test. If the disturbance disappears the machine insulation or associated wiring and equipment (potential transformers, leads to potential transformers, lightning arresters, and so forth) should be investigated as possible sources.

When the analyzer is used for making probe tests, the only limitation appears to be the problem of contacting the conducting coil surface with a suitable probe. In this connection a low-voltage ohmmeter is useful for checking to be certain that the probe actually is contacting the conducting material. The ohmmeter checks are made before test voltage is applied to the winding.

Figure 7. Slot discharge analyzer

Figure 6 shows a typical oscilloscope trace obtained during a test on a large stator winding. As shown, the trace with the calibrating circuit not discharging is small compared to that obtained with the calibrating circuit discharging. In general, when the trace obtained under normal conditions is 30 per cent or less than with the calibrating circuit discharging, the winding is considered to be discharge free. This residual trace is that conducted in from the source of test voltage. The magnitude of this residual is the principal limitation to the sensitivity of the analyzer. Figures 7 and 8 show respectively the analyzer and the equipment being used to test a large hydrogen-cooled stator winding.

SUMMARY

A sound preventive maintenance program for any type of electric equipment is achieved most effectively when there is an understanding of the potential sources of trouble which may be in need of adjustment, repair, or

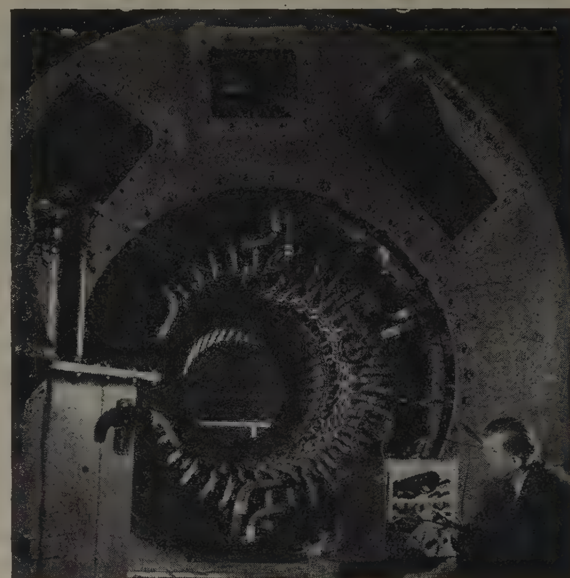

Figure 8. Slot discharge test on a turbine-generator stator

replacement. Knowledge of the potential trouble sources is gained by experience and intelligent analysis of the performance record of the equipment involved. In the case of high-voltage generators the exceptionally fine performance record makes it necessary to examine the performance of relatively large numbers of machines to get a good over-all perspective of the potentialities for distress.

In a complex piece of equipment such as a large generator, it is seldom, if ever, possible to develop a single test which gives a complete and accurate picture of the insulation conditions of the various components. It has been found possible, however, to further the cause of diagnostic testing on these machines by developing several tests each of which are directed toward detecting particular types of trouble which experience has shown are possible. Slot discharge detection techniques are an example of this particular type of test. It is a single-purpose instrument designed specifically for use in detection and location of discharging between conducting coil surfaces and slots in high-voltage stator windings.

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Analysis of Unexcited Synchronous Capacitor Motors

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A CAPACITOR-RELUCTANCE MOTOR is a miniature salient-pole synchronous machine with a squirrel-cage damper winding and unsymmetrical stator windings connected in unsymmetrical circuits. The basic theories applicable to such a piece of synchronous machinery, namely, the symmetrical components, the 2-reaction theory, and the cross-field theory, are well established in engineering literature, and the purpose of this article is to deduce from these theories a comprehensive representation of the capacitor-reluctance motor from which the motor characteristics—for example, the starting torque, synchronous pull-out torque, torque angle, efficiency, and so forth—can be calculated readily with useful accuracy.

The basic idea underlying the theoretical deductions is to consider the rotor, the squirrel-cage winding, and the uneven air gap as an integral entity, and to study its interaction as a whole with the stator currents.

At synchronous speed, the stator currents can be resolved into positive and negative sequence components. The positive sequence component is locked into synchronism with the rotor, while the negative sequence component rotates in the opposite direction at twice synchronous speed. For the positive sequence component, this rotor entity can be represented by a simple passive network consisting of three elements: the reactances $jX_Q, j(X_d - X_Q)$ and a resistance R_b, the value of which depends on X_d, X_Q, and the torque angle δ only. The electric power consumed by R_b represents the mechanical power developed. For the negative sequence component, the rotor behaves essentially the same as an ordinary squirrel-cage rotor.

With the aid of the symmetrical components, the complete equivalent circuit for a capacitor-reluctance motor is derived and shown in Figure 1. R_b is the only circuit element which changes with the load angle δ. The other circuit elements remain constant under all load conditions at synchronous speed. The performance curves of a 1/8-horsepower 4-pole capacitor-reluctance motor are calculated and compared with test results in Figure 2.

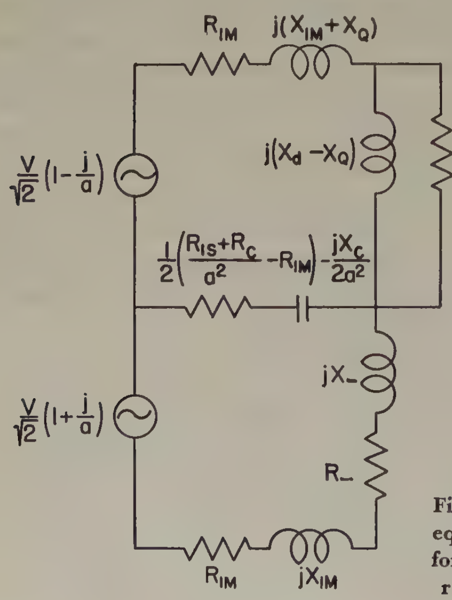

Figure 1. An equivalent circuit for the capacitor-reluctance motor

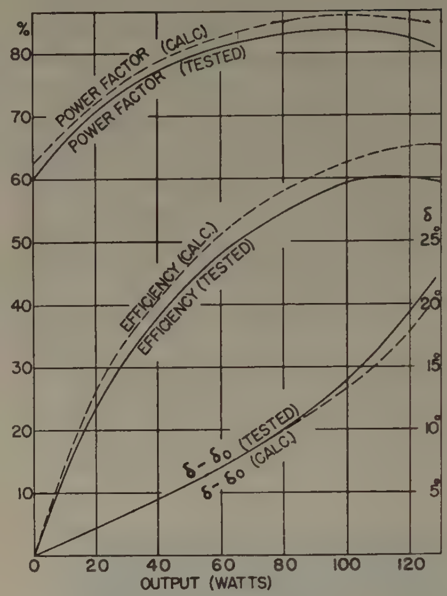

Figure 2. Performance curves for a 1/8-horsepower 4-pole capacitor-reluctance motor

At locked-rotor condition, the stator currents are resolved along the two rotor axes, and the rotor reaction can be determined from its impedances along these two axes. Based on a torque equation from the cross-field theory, the starting torque is found to be

$$T = aI_mI_s \sin\theta_{sm}(R_{ed}+R_{eQ}) + I_k^2 \sin 2(\Delta_k+\Delta)(X_{eQ}-X_{ed})$$

where I_m and I_s are the main and auxiliary winding currents respectively; I_k is a current depending on the relative magnitude and angle of I_m and I_s; θ_{sm} is the phase angle between I_s and I_m; R_{ed}, R_{eQ}, X_{ed}, and X_{eQ} are the apparent rotor resistances and reactances along the d and Q axes respectively; and Δ_k and Δ are angles indicating the rotor position relative to the stator.

The starting torque consists of two terms: an induction motor torque which is independent of rotor position and a synchronous motor torque which varies sinusoidally with respect to the rotor position. The second term is undesirable as it creates low points of the starting torque. It can be eliminated by increasing the slot leakage reactance of the rotor slots located below the enlarged air gap so that

$$X_{ed} = X_{eQ}$$

Digest of paper 51-364, "An Analysis of Unexcited Synchronous Capacitor Motors," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Slot Discharge Detection in High-Voltage Generators During Operation

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Using frequency sensitive equipment across all or part of the neutral impedance, this modified slot discharge detection method permits tests without shutting down the machine or using auxiliary high-voltage equipment. Tests on eight large water wheel generators indicate that the method is generally applicable if there is a current transformer or other impedance in the generator neutral.

SLOT DISCHARGE IS a result of poor contact between the conducting surface on a generator coil and the stator iron. Discharges of this nature can be very severe because of the high current involved and can cause serious damage to the coil insulation. If permitted to continue, small pin holes or craters will develop in the insulation because of the dehydration of the mica. Eventually this will result in failure of the coil.

Basic work on slot discharge detection has shown that this disturbance is most readily detectable in the audio-frequency range. Fundamentally the problem is one of discriminating between the disturbance created by the surface discharging and that created by other effects such as internal void ionization, end winding surface corona on the machine under test, and residual harmonics or other disturbance existing in the test voltage. The sensitivity of any detection scheme is limited by the level of residual disturbance and the ability to isolate the discharge disturbance from the residual.

In the use of the slot discharge analyzer either for probing or detection, the test voltage is supplied from an external source. The testing transformer usually is effective in filtering out much of the residual source disturbance. When this is not the case, it is always possible to use a line filter to accomplish this objective.

The purpose of the present work is an attempt to further simplify the detection problem. It was believed that on those machines having current transformers or some other impedance in the generator neutral there exists the possibility of detecting slot discharging by connecting frequency sensitive circuits across generator neutral impedance. With this method it was recognized that it is not possible to separate source harmonics (which in this case is the generator itself) from the disturbance due to surface discharging.

MACHINE HARMONICS

IN THE RANGE of magnitudes of interest (extremely small values), machine harmonics may be the result of a number of factors difficult to calculate or control. The principal harmonic of interest is the slot harmonic.

The order of this harmonic is approximately equal to the number of slots per pair of poles. Harmonics of this slot frequency are also possible. Other harmonics are possible because of the interaction between the stator slots and the damper winding. Also, the accuracy of field pole spacing and other causes may influence the machine harmonics.

In the design of machines, the principal concern in connection with these higher harmonic frequencies is to meet or come well within telephone interference or influence factor limits. This factor is the ratio of the square root of the sum of the squares of the weighted values of harmonic components to the rms value of the wave. When the machines meet these limits, the exact magnitude and frequencies of these very small harmonics have not received much attention.

The only alternative in connection with this method of slot discharge detection is to explore the frequency spectrum and find a frequency or frequency band where residual harmonics are small compared to the disturbance caused by surface discharging.

For an effective test, it is believed that the residual should be in the range of 1/5 to 1/10 of the smallest possible disturbance caused by slot discharging. This minimum disturbance would be that resulting from one discharging coil side in the machine winding.

To check the sensitivity or discrimination of the various filters in the test, it was necessary to produce a calibrating signal equal in magnitude to the minimum discharge disturbance. Insulated test bars simulating coils were used for this purpose. The bars were 54 inches long. The central 30 inches of the bars were prepared with a conducting surface finish similar to that used on high-voltage stator coils. The several bars were prepared with resistivities in the normal, moderately high, and extremely high range of surface resistivities. Sheet metal cells 26 inches long simulating stator coil slots were made. The test bars were assembled in the cells but insulated from the cells so that a small air gap existed between the conducting coil surface and the grounded metal cell (simulating conditions which give rise to slot discharging). A small adjustable gap was connected between conducting coil surface and the grounded cell. When this gap opening

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was made small (0.001 to 0.005 inch), the discharge voltage from coil surface to ground was limited to approximately the minimum sparking potential. Closing the gap entirely grounded the coil surface and suppressed the discharging. The test bars were connected successively to a machine terminal, depending on the coil surface resistivity desired. So connected, the bar producing the calibrating signal was at the greatest possible distance from the detection point (the neutral). It was therefore possible to reproduce discharge disturbance smaller than would be produced by a single coil side (coil side slot portions were generally longer than the test bars) having either normal or high surface resistance. The test setup for producing the calibrating signal is illustrated in Figure 1.

The detection circuits studied consisted of a series of single-frequency high-pass and band-pass filters used in combination with a cathode-ray oscilloscope. Figure 2 is a diagram of test connections and also lists the characteristics of the filters used. As shown, the input terminals of the filters were connected across a portion of the impedance plus 1/8 or 1/9 of the neutral resistance. For the machine studies, the neutral resistance was in the range of 40 to 80 ohms. Tests also were made by connecting only across the primary of the neutral current transformer. The output of the filters was observed with a cathode-ray oscilloscope. Output and input resistances of the filters were 500,000 and 1,000 ohms respectively. The input level of the filters was 8 volts. The voltage gain of the filters was approximately 15 decibels in the passband or at the tuned frequency in the case of the single-frequency filters. The cutoff for all the filters was relatively sharp, being 45 decibels per 1/2 octave.

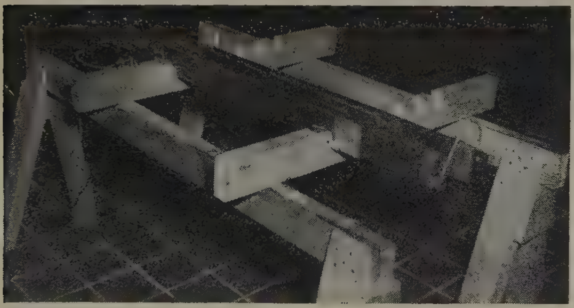

Figure 1. Test setup for producing the calibration signal

TESTS AND RESULTS

Of the 8 machines tested, three were 40,000-kva 13.8-kv 150-rpm vertical water wheel generators at one location; 37,500-kva, 6.6-kv, 164-rpm at another; and four 20,000-kva 13.8-kv $171^1/_2$-rpm machines at another powerhouse. Residual harmonics were measured with each of the filters. Tests were made with the machines on the line under various conditions of loading from no load to full load on each machine type. Tests also were made with all filters on machines of each type running but not connected to the line. The residual was measured on each machine with the 4- to 10-kc band-pass filter. The relative sensitivity of the filters to residual harmonics and the slot discharge calibrating signal was observed. The relative sensi:ivity as a function of normal and moderately high coil surface resistance and for a strong and very minute discharge was determined on each machine type using all filter combinations.

The results of the tests are outlined in Tables I and II. Briefly these may be summarized as follows:

1. It was found that the residual disturbance when the machine was on the line was high for any filter and that the surface discharge was undetectable under these conditions. One curious condition noted in this connection was that while the big jump in residual occurs when the machine was connected to the line, a further increase of between 3 and 5 to 1 occurred in going from no load to full load. The reason for this change with load is not apparent. To further explore this, two machines were paralleled (not connected to the line) and loaded up to rating with leading and lagging kilovolt-amperes respectively. In this case there was no difference in residual with change in stator amperes.

2. When the machines were off the line, the residual harmonics were found to be small compared to the calibrating signal for several of the filters. The 4- to 10-kc band-pass filter was found to be most effective. For this filter, the residual was in the range of 2 to 10 per cent of the discharge calibrating signal for the machine tested. Figure

Table I. Results of Tests on Three Generators

Filter Used	Residual Voltage, No Discharge, Filter Output, Maximum Millivolts, Double Amplitude: Full Load	Half Load	Quarter Load	No Load	Generator Isolated	Discharge, Disturbance, Filter Output, Maximum Millivolts, Double Amplitude, Generator Isolated: Low Surface Resistance: Millivolts	Per Cent Residual Discharge	High Surface Resistance: Millivolts	Per Cent Residual Discharge
Number 3 Generator, Calderwood									
1,046-cycle					348	380	91		
1,568-cycle					81	163	50		
2,349-cycle					81	130	62		
3,520-cycle					12.2	40	30		
2.5-kc high-pass					174	522	33		
2.5- to 4-kc band-pass					174	290	62		
4- to 10-kc band-pass	580	425	275	185	12.6	146	8.6	87	14.5
Number 5 Generator, Cheoah									
1,046-cycle					58	64	91		
1,568-cycle					29	44	67		
2,349-cycle					14	46	30		
3,520-cycle					5	26	21		
2.5-kv high-pass					26	130	21		
2.5- to 4-kc band-pass					23	102	23		
4- to 10-kc band-pass	240	208	160	96	5	107	4.7	93	5.4
Number 1 Generator, Cheoah									
1,046-cycle					32	50	67		
1,568-cycle					23	93	25		
2,349-cycle					14.5	102	14		
3,520-cycle					3	90	3		
2.5-kc high-pass					14.5	960	1.5		
2.5- to 4-kc band-pass					11.6	240	4.8		
4- to 10-kc band-pass	382	313	313	290	6	348	1.7	230	2.6

3 illustrates the difference in disturbance between the residual and the discharge signal for the three machine types using the 4- to 10-kc band-pass filter. In comparing these pictures consideration should be given to the difference in oscilloscope deflection sensitivity for the two conditions of test.

3. As would be expected, coil surface resistivities and the magnitude of the discharge voltage have an effect on the magnitude of the detectable discharge signal. Discharges were found to be definitely detectable for normal and moderately high surface resistivities with very minute discharge potentials. Based on the tests, it is estimated the discharging with surface resistivities up to several hundred thousand ohms per square would be detectable by this method.

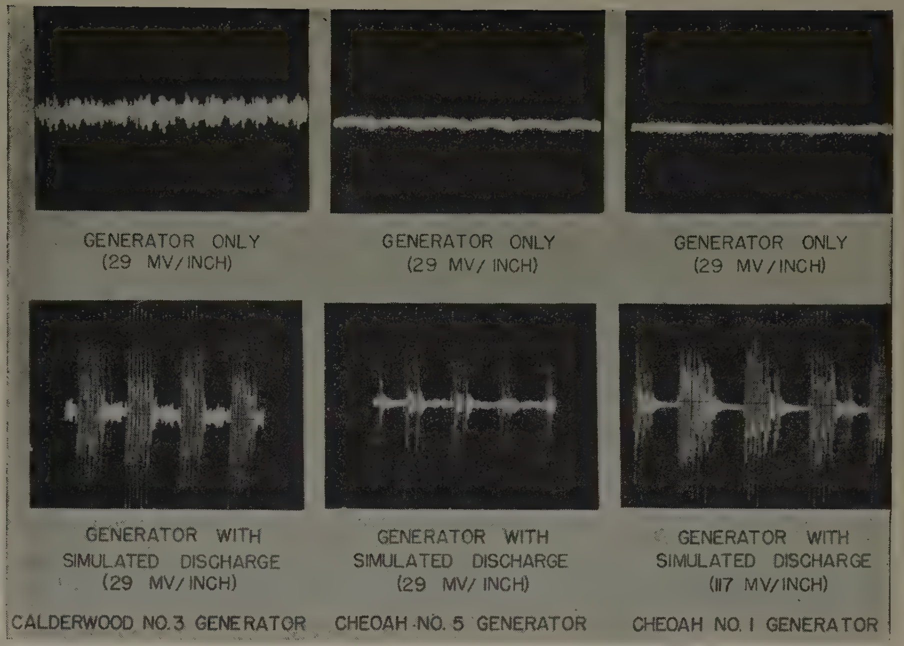

Figure 3. Sensitivity tests of discharge detection circuit on water wheel generators

Slot discharge, if permitted to continue, eventually will damage insulation to the point where failure will occur. A simple method of detecting slot discharge with the unit running normally is desirable.

Based on the studies made on these machines, the following conclusions are believed to be justified:

1. The tests made have demonstrated the feasibility of detecting the existence of surface discharging by test from the neutral for the machines studied. It was necessary, however, to make these measurements with the generator isolated from the line because of an unusual amount of noise on the line at the time of tests.

2. The 4- to 10-kc band-pass filter was shown to have the greatest sensitivity for discharge detection by this method.

3. It is believed that this method is generally applicable to machines which are not solidly grounded at the neutral. It was found that the disturbance was detectable by connecting across the primary of the neutral current transformers.

4. Where applicable, this method represents a definite test simplification since it is not necessary to shut the machine down or provide an external source of test voltage. Another possible advantage is that normal machine vibrations incident with machine operation are present during the test.

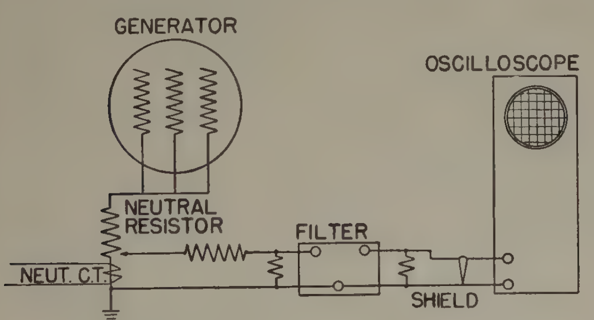

Figure 2. Discharge detection circuit

Filters used: 1,046-, 1,568-, 2,349-, 3,520-cycle single frequency; 2,500-cycle high pass; and 2,500-, to 4,000- and 4,000- to 10,000-cycle band-pass

Table II. Residuals Measured for All Generators with 4-to 10-kc Band-Pass Filter

Generator		Full Load, Millivolts	No Load, Millivolts	Generator Isolated, Millivolts
Calderwood number	1			9
	2			35
	3	580	185	13
Cheoah number	1	382	174	6
	2			6
	3			5
	4			4
	5	240	96	6

1852—Centennial of Engineering—1952

Completion of the 37-man Board of Directors who will head the Centennial of Engineering celebration to be held in Chicago, Ill., from July 1 to September 30, 1952, was announced recently. The Centennial, which is being sponsored by 41 national and international groups that include in their membership the great majority of the engineering profession in the United States, will mark the 100th anniversary of the establishment of engineering as a recognized civilian profession in this country. Prior to 1852, when the American Society of Civil Engineers was founded, important engineering work in this country was conducted by military engineers. Prominent Directors include Gano Dunn, David Sarnoff, Herbert Hoover, Benjamin Fairless, Carlton S. Proctor, Titus G. LeClair, and many others.

High-Power Vacuum Tubes for Industrial Heating

H. D. DOOLITTLE

IN ANALYZING vacuum-tube failures the principal troubles are: 1. seal breakage; 2. short-circuited grid cathode structure due to weak seals or warping of the high-temperature filament; 3. excessive filament temperature causing rapid evaporation of cathode material; 4. overheated anodes with heavy scale formation and premature failure due to anode puncture; 5. excessive grid dissipation resulting in grid distortion; and 6. gassiness due to momentary overload. Fortunately, most of these evils can be corrected easily. There is, however, no cure for excessive filament temperature except getting a tube with sufficient cathode emission so that it will be capable of the job for which it was designed.

A series of improved tubes has been designed to cover the power range from 5- to 200-kw output power. These tubes follow the same general pattern. The best possible techniques are used to provide strong seals, grid and filament structures free of strains, thoroughly outgassed parts, and thick copper high-dissipation anodes. Figure 1 shows the *ML-5682* tube which is designed for 200-kw power output.

Figure 1. ML-5682 tube for 300-kw input

Seal breakage is reduced greatly by the use of a strong alloy of nickel-iron called kovar in place of the older type of seal which used thin soft copper.

The filament presents a particularly tough problem due to its high operating temperature. It is made of pure tungsten or tungsten with a small percentage of thorium and operates at 1,600 to 2,200 degrees centigrade; for good life and proper emission its temperature cannot vary by more than ±20 degrees centigrade. At these temperatures it has a strength comparable with annealed copper at room temperature. As the filament heats up it will expand about 1/8 inch for a 4-inch length, and hence provision must be made for free expansion to prevent bowing with resultant grid-cathode shorting. It has been common practice to tension the filament structure to keep it straight. We have found, however, that all attempts to tension a filament with a spring lead to excessive short-life failures due to binding or warping of the support structures. The acid test of freedom from bowing is the static test data which define the relative position of cathode, grid, and anode. Table I shows such data taken on a 20-kw *ML-5658* tube at 0 hours and after nearly 10,000 hours of service. A shift of 1 kv in the Eb_1 test is equivalent to a change of 0.015 inch in the grid-cathode spacing. This tube has maintained its filament stability for nearly 10,000 hours to within a few thousandths of an inch. The filament current has fallen from 321.6 amperes to 313.0 amperes due to tungsten evaporation.

Table I. Static Test Data on ML-5658 20-Kw Tube Before and After 9,700 Hours of Life

Test	Prior to Shipment	After 9,714 Hours of Service
Filament current	321.6	313.0 amperes a-c
Grid biased 200 volts negative with plate current 2 amperes, plate voltage =	7.25	7.25 kv d-c
Grid at zero potential with plate current of 2 amperes, plate voltage =	3.0	3.05 kv d-c
Amplification factor	21.2	21.0
Plate voltage at 10 kv, grid cutoff voltage =	−530.0	−540.0 volts d-c

The grid structure uses large wire diameters and the grid is etched carefully to cool efficiently by radiation.

The anode of power tubes consists of a copper cylinder from $1^1/_2$–4 inches in diameter, closed at one end. The active electrode structure is supported within this cylinder and attached to it by glass insulation at the other end. The heat is removed from the anode proper by water cooling or by fins and air cooling. The conventional use of thin walls on the anode cylinder leads to hot spotting. These industrial tubes use a thick section of copper which distributes the heat uniformly and allows much greater anode dissipation. Such an increased safety factor is essential to good tube life in industrial service.

Digest of paper 51-355, "The Design of High-Power Vacuum Tubes for Industrial Heating Applications," recommended by the AIEE Committee on Electronics and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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A Universal Power Circle Diagram

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THE USEFULNESS and utility of the conventional power circle diagram can be expanded by translating the origin from the zero of power to the center of the circle. This operation makes all the circles concentric so that they can be printed beforehand on standard sheets of paper. Data for a particular problem then are plotted on the sheet as required. Because of the number of circles that are available immediately, the diagram also can be used for solving problems in which either the receiving- or sending-end voltage is a variable. Such solutions are aided by the plotting of auxiliary loci, which are either straight lines or circles, for constant loss, constant power, constant power factor, and so forth.

Since the receiving- and sending-end circles have the same radii, this translation of the origin places the receiving- and sending-end operating points on the same circle. If M_R, N_R are the new co-ordinates of the receiving-end operating point, and M_S, N_S are the new co-ordinates of the sending-end operating point, then it can be proved that the receiving-end operating point has the polar co-ordinates $R/\underline{(\beta-\delta)}$ and the sending-end operating point has the polar co-ordinates $R/\underline{180°+(\beta+\delta)}$, where $R^2=(e_Se_R/b)^2=M_R^2+N_R^2=M_S^2+N_S^2$; δ is the phase angle between e_S and e_R; and the general circuit constant $B=b/\underline{\beta}$. Also the zero of receiving-end power is at the end of the phasor $e_R^2(\boldsymbol{A}/\boldsymbol{B})$ while the zero of sending-end power is at the end of the phasor $e_S^2(\boldsymbol{D}/\boldsymbol{B})$. These relations are shown in Figure 1.

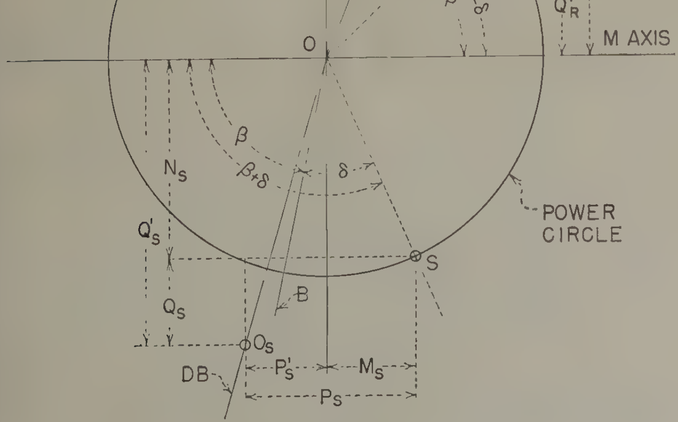

Figure 1. General relations of the universal circle diagram

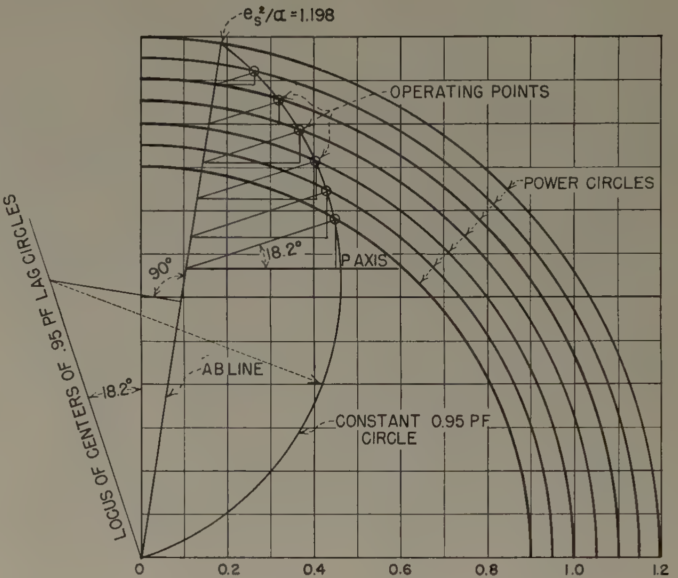

Figure 2. Diagram illustrating the use of constant power factor circle

It will be noted that receiving-end operation occurs in the first quadrant, while sending-end operation occurs in the third and fourth quadrants. By a rotation of axes the sending-end diagram can be superimposed on the receiving-end diagram so that only the first quadrant need be used. The universal diagram, therefore, consists of a set of Cartesian co-ordinates superimposed on one quadrant of a set of polar co-ordinates. The diagram is calibrated in per unit, and when the megavolt-ampere base of the general circuit constants is selected so that b is unity, the radius of the operating circle is e_Se_R, and the operating point lies on the radius vector $\beta-\delta$ (receiving end), or $\beta+\delta$ (sending end). Zeros for receiving- and sending-end power are at the polar co-ordinates $ae_R^2/\underline{\beta-\alpha}$ and $de_S^2/\underline{\beta-\Delta}$ respectively, where $\boldsymbol{A}=a/\underline{\alpha}$, $\boldsymbol{D}=d/\underline{\Delta}$.

Figure 2 illustrates the use of the diagram for a problem in which the sending-end voltage and receiving-end power factor are constant. The radial lines calibrated as $\beta-\delta$ or $\beta+\delta$ are not shown because they were not required for this problem. From Figure 2 an auxiliary curve of receiving-end voltage versus receiving-end power can be plotted.

It will be found that plotting auxiliary curves from the diagram involves considerably less labor than plotting from point-to-point computations. By making the diagram a suitable size, any desired degree of accuracy can be attained.

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Electron Tube Experience in Computing Equipment

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A. W. BROOKE

The malfunctioning or failure of electron tubes in a computer is a large item in the over-all cost of its operation. Preventive maintenance testing of tubes before installation has proved to be economically feasible. Methods of testing and the findings are given in this article.

IT IS DESIRABLE that electron tubes for use in commercial computing equipment have a high degree of reliability throughout a predictable life expectancy. Considerable study is being applied to the question of electron tube reliability by almost everyone concerned, and new designs and better production methods for standard designs are being evolved continuously for more reliable tubes. To encourage this advancement and direct its trends for a given application, it is best to analyze the results obtained from the use of electron tubes under actual operating conditions. Only in this way can the final answer be obtained as to the type of improvements best needed or the results of modifications or changes already attempted. For this reason a tube analysis program has been operated by the International Business Machines (IBM) Corporation and the purpose of this article is to outline the program and to give samples of some of the results obtained.

At present the IBM Corporation has 2,500,000 electron tube sockets active in the field of commercial computation equipment, approximately two-thirds of which are reported on at regular intervals concerning the tube failures in service. A monthly average of 2,700 returns are analyzed by the IBM Tube Laboratories under a defective-tube analysis program established 2 years ago. Approximately 1,000,000 new tubes a year are given individual incoming inspection tests, and lot sample life tests are performed on each incoming lot of tubes from the manufacturer for 1,000 hours prior to their production use. Robot life tests are carried out continuously on specific circuit applications. In addition, tube analysis records have been maintained since 1947 on the 12,800 sockets in the IBM Selective Sequence Electronic Calculator (SSEC).

INCOMING INSPECTION

EVERY TUBE as it is received from the manufacturer is inspected before use. These tests are organized to simulate operating requirements and remove obvious defects and inoperative tubes. Common characteristics, cutoff and conduction plate currents, gas, grid emission, screen current, short circuits, microphonism, and functional operation are checked individually. The limits in some cases are tighter than Joint-Army-Navy (JAN) specifications for comparable receiving-tube types. The distribution of common defects on each incoming tube lot is watched closely to detect initial shifts on the manufacturers' control of critical characteristics. In Figure 1 is shown the proportion of rejects experienced for each of seven common tube types used in IBM equipment. The *6B3001* is a specially designed pentagrid amplifier for use where dual grid control is desired for switching operations.

In Table I the percentage of rejections for each cause is shown by tube type. Low plate current (under zero bias conditions) and faulty cutoff have been found to fluctuate from time to time for various manufacturers. Since the acceptance limits, however, are in many cases more rigid than for receiver tube specifications, it is believed the manufacturers are doing a commendable job in supply. Despite the particular design of the *6B3001*, it suffers equally with all close-spaced types from an initially large percentage of lint and conductive particle short circuits associated with standard receiver-tube assembly conditions. The *6B3001*, with 87 per cent of incoming rejections due to intermittent short circuits caused by lint and conductive particles, has the highest initial percentage of rejection of any tube type on incoming inspection (Figure 1) and the lowest per cent rate of failure in service (Figure 3).

The lint and conductive particles are detected by a special unit shown in Figure 2 and are checked at a minimum of 10.0 megohms between all elements except heater and cathode. The tubes are rotated while under vibration and in a horizontal position. Lint and particles thus are forced to fall through the grid-cathode and other critical spacings and if present in sufficient quantity will indicate

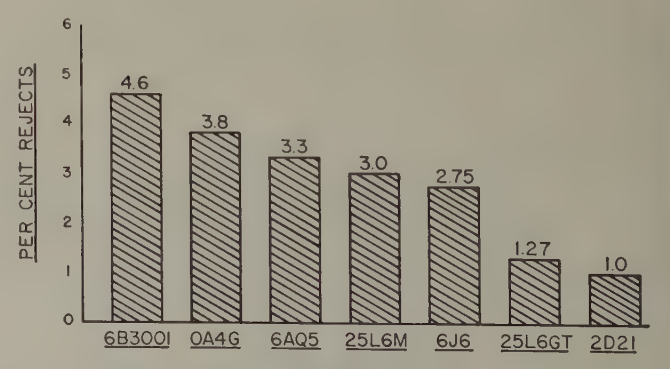


Figure 1. Proportion of rejects for each of seven common tube types on incoming inspection

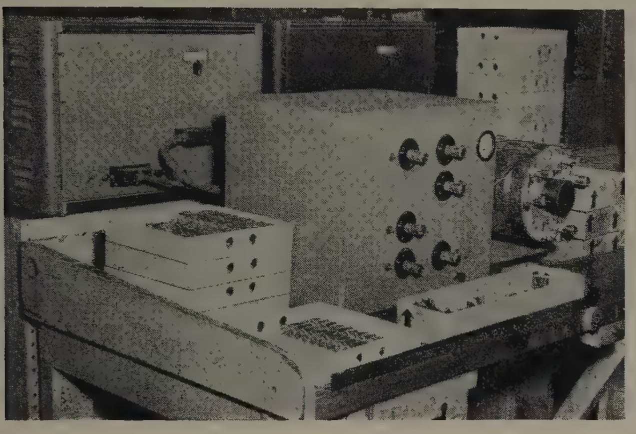
Full text of a paper presented at the Joint AIEE-Institute of Radio Engineers Conference on Electron Tubes for Computers, in collaboration with the Panel on Electron Tubes of the Research Development Board, at Atlantic City, N. J., December 11–12, 1950.

J. A. Goetz Brooke is with the International Business Machines Corporation, Poughkeepsie, N. Y., and A. W. Brooke is with the International Business Machines Corporation, New York, N. Y.

Table I. Tabulation of Cause for Rejection on Incoming Inspection of Five Different Tube Types

CAUSE OF REJECTION	PER CENT OF TOTAL				
	6B3001	6J6	25L6GT	25L6M	6AQ5
SHORTS	87.0	74.0	36.0	9.0	29.0
HIGH SCREEN CURRENT	0.0	0.0	16.0	51.0	0.0
FAULTY CUT-OFF	5.0	23.0			45.0
GASSY TUBES	0.0	0.0	20.0	34.0	0.0
HEATER DEFECTS	1.0	0.0	13.0	0.0	0.0
LOW PLATE CURRENT	7.0	3.0	15.0	6.0	26.0

Figure 2. Testing equipment for the detection of lint and conductive particles. The tube is rotated while under vibration



as intermittent short circuits. Since this unit has been in service, the number of failures occuring in service because of such short circuits has been reduced materially.

RATE OF TUBE FAILURES AS A FUNCTION OF TYPE

THE GENERAL operating performance of a number of tubes is shown in Figure 3. This information on tube failure rates is an average for a 9-month period ending October 2, 1950. The per cent rate of failure figure shown as abcissa is the number of failures, as a per cent of total tubes of that type in use, experienced per thousand hours of equipment operation. This figure also indicates the comparative rate of failure existing between the commercial equipment and the SSEC for similar tube types.

The following points are of interest. First, the rate of failure is the highest for tubes on the left of the graph, which include the high heater-voltage types. The failure rate is about equal for field machines and SSEC use on these types despite the fact that a much longer period of operation has been experienced for the majority of the SSEC tubes. The *6B1000* is an early modification of the standard type *6BE6* miniature pentagrid amplifier for switching operation, and has been replaced largely by the *6B3001*. The two tubes are functioning identically as switch tubes, however, and the latter indicates about a 15-to-1 reduction in rate of failure over the former.

The rate of failure shown as an average can vary for many reasons. Figure 4 presents a history of the observed rates of failure of three tube types employed throughout the SSEC for equal periods of 1,000 hours during an 8,000-hour interval of equipment operation. Greater fluctuation about an average value (at right hand of each curve) is noted for the *25L6GT* and the *12SN7GT*, but both types remain identifiable and under control during this period.

As it is known that tubes will fail in service, it is therefore expedient to instigate some form of preventive maintenance in order to detect tubes which are potential causes of improper operation. A simple form of preventive maintenance is employed on individual units of the SSEC. Figure 5 shows a study of the results of its application to a particular problem. The electronic storage unit of this calculator employs 640 type-*25L6GT* tubes in relay pickup service. Originally a high rate of tube failure existed in this application where, prior to the introduction of preventive maintenance, an average of 104 tubes failed per thousand hours of machine operation.

A test was arranged in which a calibrated resistor load was substituted for each of the relay loads during normal calculator operation. This entails no tube removal and is handled by dial switch insertion. Records are kept of the waveform and pulse amplitude for each tube during the preventive check, and those failing below certain arbitrary limits are replaced. This check occupies 45 minutes for a total of 640 tubes and, together with increased experience, has resulted in the reduction noted as we move

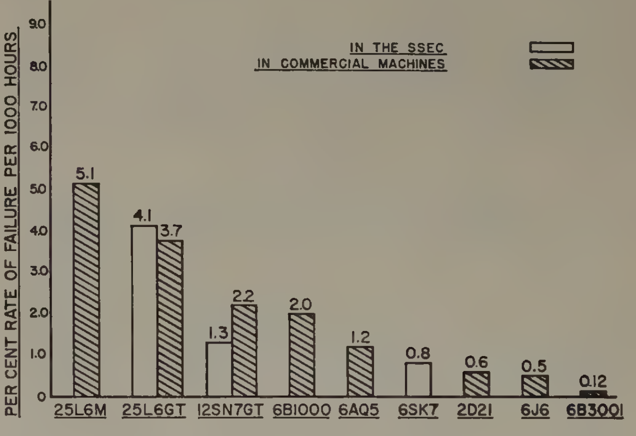


Figure 3. Examples of rate of failure by type for certain of the tubes used in IBM commercial machines and in the SSEC

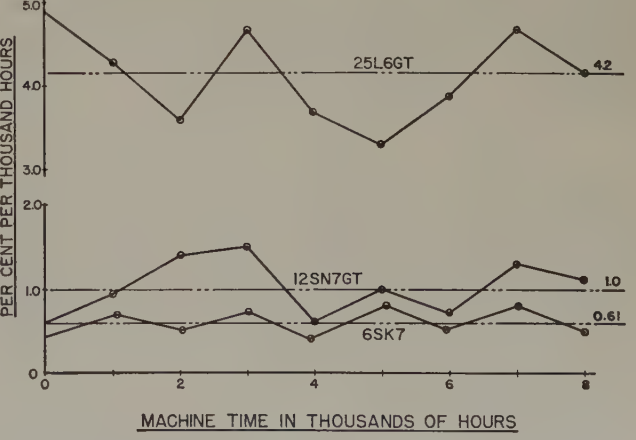


Figure 4. Variation of rate of failure over a period of 8,000 hours for three tube types used in the SSEC

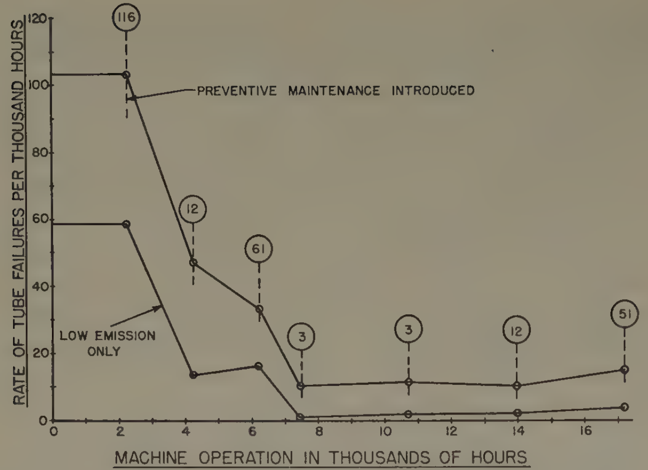


Figure 5. Effect in one unit of SSEC of preventive maintenance upon total rate of failure and low emission rate of failure

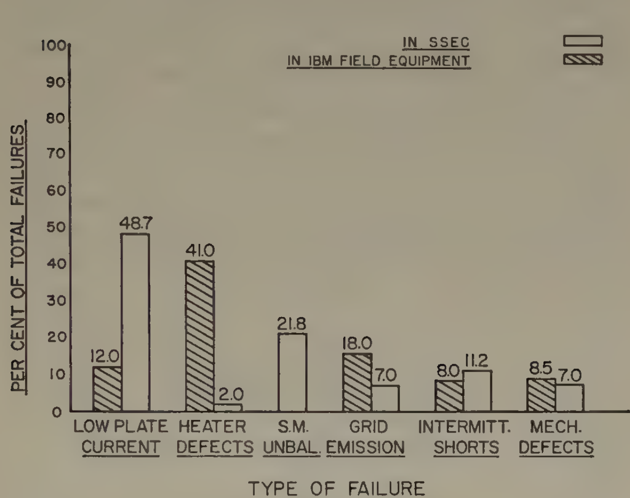


Figure 6. Major causes of failure for certain tube types used jointly by the SSEC and IBM commercial machines

to the right on the figure. The number of tubes removed during each check are circled and, for the period covered by the figure, total 258 tubes. During this same period, the rate of failure has been reduced to 10 per cent of the initial value while low-emission failures are now only a fraction of their initial portion of total failures.

The cost of such tube removals by preventive maintenance is small on the SSEC (which costs approximately 5 dollars a minute to operate) when compared to the reduction of reruns due to error and time spent in trouble location.

COMMON CAUSES OF TUBE FAILURES

MORE DETAILED ANALYSIS of the data is necessary for corrective measures than has been given so far. Figure 6 illustrates the cause and the frequency of failure for certain tube types used jointly by the SSEC and IBM commercial machines. Low-emission or plate current slump is the chief cause of failure in SSEC tubes, while heater failures are worse among field equipment employing these types. This is explained partly by the fact that a much longer period of operation has been experienced by the majority of SSEC tubes analyzed at this time. Heater life definitely is lengthened in the SSEC, however, by reducing shutdowns to a maximum of four or five times annually. A majority of heater failures are found to occur immediately following resumption of service after such shutdowns. Loss of emission with life is not as large as would be expected on field equipment, but this cause is masked by the high incidence of other defects and the constant addition of new machines to the field. Grid emission is present in noticeable quantities on these types, and has been found to develop rapidly in early stages of operation life for high heater-voltage tubes.

By way of comparison, Figure 7 illustrates the types of failures found on miniature tubes employed generally in the IBM Electronic Calculator Punch, type *604*, and the IBM Electronic Statistical Machine, type 101; these tubes are the *6J6*, *6AQ5*, *6B3001*, and *2D21*. Here it can be seen that low plate current and defective cathodes combined account for almost two-thirds of all failures in service. Intermittent short circuits and arcs are appreciably higher than on the *GT* types and heater defects are much lower than for the high heater-voltage types.

A more detailed presentation of the proportion of failures for each tube in this service is given in Table II. A look at type *6AQ5*, for example, would indicate that 50.0 per cent of all failures are charged to intermittent short circuits and arcs as compared to 11.0 per cent for type *6B3001* and 12.0 per cent for type *6J6*. Type-*6J6* failures are led by low plate current and cathode defects, together totaling 64.0 per cent of all causes of failure.

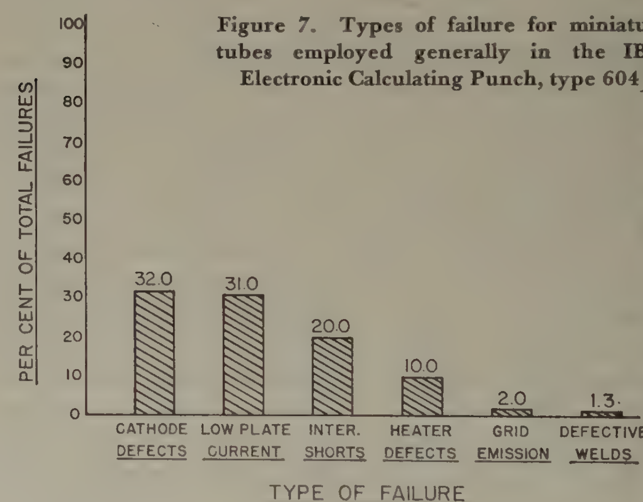


Figure 7. Types of failure for miniature tubes employed generally in the IBM Electronic Calculating Punch, type 604

Table II. Proportion of Failures for Some Tube Types in the IBM Electronic Calculating Punch, Type 604

CAUSE OF FAILURE	PER CENT OF TOTAL FAILURES		
	6B3001	6J6	6AQ5
INTERMITTENT ARCS AND SHORTS	11.0	12 0	50.0
LOW PLATE CURRENT	15.0	21.0	23 0
CATHODE DEFECTS	17.0	43.0	18.0
FAULTY CUT-OFF	7.0	8.0	2.0
GRID EMISSION	5.0	9.0	
DEFECTIVE WELDS	40.0	2.0	
GLASS DEFECTS AND AIR TUBES	5.0	5.0	7.0

The failures for one specific tube type as an example are shown in Figure 8. This vacuum tube, type *6J6*, occupies the largest number of field sockets in the IBM Electronic Calculating Punch, type *604*, almost 700,000 being used at present. Values assigned to specific causes of failure in this figure differ from those of Table II only in the corrective action taken to eliminate the trouble so identified. It is felt that defective cathodes are aggravated by the very close spacings employed in this tube and reflect a need for closer control by the manufacturer on cathode processing.

The major type of cathode defect encountered during life is poor adherence of cathode emissive coating to base metal and results in a series of related troubles: reduced emission or low plate current due to reduced surface temperature; intermittent short circuits; and increased leakage across electrode spacers due to cathode base-metal evaporation.

To conclude this discussion of cause and frequency of operational tube failure, experience has indicated that such failures are evenly divided among various manufacturers for a given tube type. Table III shows the distribution of common failures for the *12SN7GT*, which is obtained in about equal quantities from four manufacturers. In general, each manufacturer has about an equal share of the failures listed. (Unbalanced transconductance is the cause of a majority of failures occurring in trigger circuit applications of this dual triode and does not cause trouble in other circuits employing this type.)

LIFE EXPECTANCY AND TUBE SURVIVAL

LIFE EXPECTANCY AND tube survival studies are vitally important for planning and help in making decisions on maintenance and operating procedures. Tube survival has been studied for some time on individual units of the SSEC. Figure 9 depicts two curves: survival and life expectancy of tubes used in relay pickup circuits. These circuits exhibit the highest rate of tube replacement in the calculator, and therefore the data shown should not be construed to represent tube life in the calculator as a whole.

Survival is expressed by the scale to the left as the per cent of the total number of tubes included in this study, 3,400, which are operating at any point on the time scale at the bottom of the figure. The data cover 30,000 hours of machine operation at this time. It should be noted that

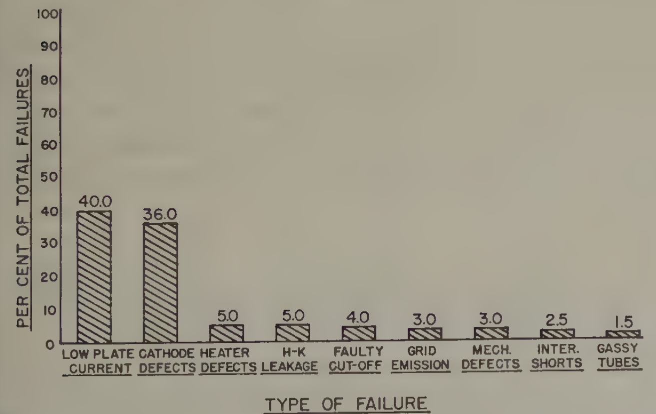
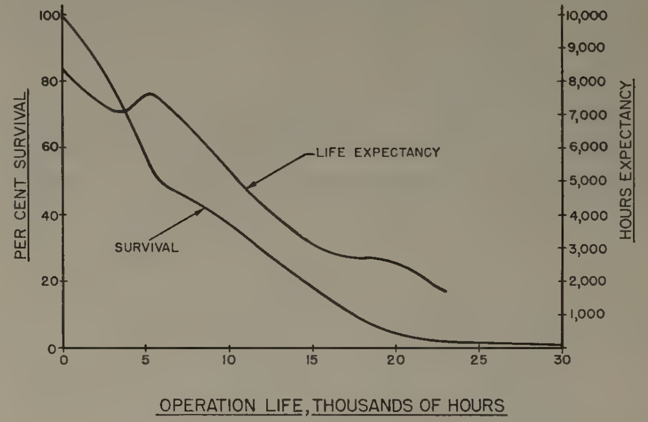


Figure 8. Type of failures for tube type 6J6 employed in the IBM Electronic Calculating Punch, type 604

Table III. Comparison of Failures in Operation of 12SN7GT Type Tubes Obtained from Different Manufacturers. Total Rejects—1,150 Tubes

DEFECT \ VENDOR	A	B	C	D
TRIODE UNBALANCE	63.3	65.2	61.3	65.3
LOW PLATE CURRENT	27.0	14.3	23.0	23.4
INTER'M'TENT SHORTS	4.5	10.9	8.8	6.6
DEFECTIVE HEATER	1.3	3.1	2.1	1.0
FAULTY CUT-OFF	0.6	0.2	0.3	0.1
MISCELLANEOUS	3.3	6.3	4.5	3.6

Figure 9. Survival and life expectancy curves for a special group of tubes in the SSEC



the term "original group" applies to subsequent replacements made in the sockets under study for this period, as distinguished from all tubes installed at one time. The upper curve labeled "Life Expectancy" is derived from data forming the survival curve, and is expressed by the scale at the right of the figure as hours expectancy of the tubes surviving at any point in operation life.

The resultant curves, while deviating from the accepted concept of exponential-law failures and constant failure rate, are representative of conditions found in practice for one application. The lower curve shows that the rate of failure is almost constant until the 6,000-hour point, at which time only 50 per cent of the tubes under study have survived. Since life expectancy falls steadily after a slight rise at 6,000 hours, random failures are indicated to be in the minority. The slight rise in life expectancy at this point would also indicate early life failures to be in the minority, and the majority of failures to be due to cathode exhaustion.

CONCLUSION

IT IS BELIEVED THERE is no single solution for the various tube problems encountered in commercial operation of computational equipment. In the data presented some of the varied types of problems which are encountered can be seen. Continued co-operation between the customer, designer, and tube manufacturer is felt to be essential in meeting the tube requirements of nonstandard applications in this field, and this must be aided by adequate incoming inspection and field analysis procedures.

Per-Unit Transmission-Line Constants

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FOR MANY YEARS, the per-unit or per cent method has been used to define the constants of such equipment as generators, reactors, and transformers. However, the constants of transmission lines still are expressed in terms of ohmic impedances. This fact is not important for short lines where the line impedance is generally small in relation to terminal impedances. However, for long lines, the line constants are one of the principal factors which determine the steady-state and transient power limits of the system. Therefore, it is desirable to use a per-unit system for transmission-line constants which is based upon the power limits of the transmission line.

A second difficulty which is encountered in the solution of long-line problems is the determination of the exact line constants by hyperbolic functions. This is a time-consuming task which is subject to mechanical errors. The purpose of this article is to illustrate that transmission-line constants can be generalized and expressed in per-unit terms so that the constants of any practical line can be read from a group of curves.

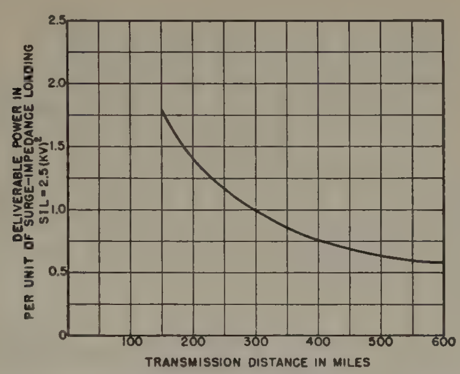

Figure 1. **Permissible loading of straightaway transmission lines as a function of line length in miles for voltages from 69kv to 500kv**

For any 4-terminal network composed of linear, bilateral elements, the sending- and receiving-end voltages and currents are related by the expressions:

$$E_s = AE_r + BI_r \tag{1}$$

$$I_s = CE_r + DI_r \tag{2}$$

The *ABCD* constants of a transmission line are complex quantities which can be expressed in terms of line length and the per-mile values of series resistance, series reactance, and shunt reactance, as follows:

$$A = \cosh\left[S\sqrt{\frac{x}{x'}}\sqrt{-1+j\frac{r}{x}}\right] \text{ volts per volt} \tag{3}$$

$$B = \sqrt{(r+jx)(-jx')} \sinh\left[S\sqrt{\frac{x}{x'}}\sqrt{-1+j\frac{r}{x}}\right] \text{ ohms} \tag{4}$$

$$C = \frac{1}{\sqrt{(r+jx)(-jx')}} \sinh\left[S\sqrt{\frac{x}{x'}}\sqrt{-1+j\frac{r}{x}}\right] \text{ mhos} \tag{5}$$

$$D = A \tag{6}$$

Shunt and Series Reactances of a Transmission Line. An examination of the quantity $\sqrt{x/x'}$ for a large number of typical transmission lines shows that the average value of this quantity is 2.06×10^{-3} (1/miles) with a maximum deviation from this value of about 0.5 per cent. Therefore, this value can be substituted in equations 3 to 6, reducing the hyperbolic quantities to functions of length and r/x ratio.

Surge Impedance and Surge Impedance Loading. The surge impedance loading (SIL) of a transmission line is defined by the equation

$$\text{SIL} = \frac{kv^2}{Z_0} \text{ megawatts} \tag{7}$$

where

$$Z_0\underline{/\zeta} = \sqrt{(r+jx)(-jx')}$$
$$\zeta = -{}^1/_2 \tan^{-1} r/x$$

Neglecting line resistance, when a line is loaded with a resistance equal to its surge impedance, the sending- and receiving-end voltages are equal and the sending- and receiving-end power factors are unity. On this basis, SIL is a desirable form of loading. However, it does not take into account the factors of line length, terminal impedances, and stability. The results of an investigation by S. B. Griscom[1] of the effect of these factors on allowable line loadings is reproduced in Figure 1. This figure shows that for long lines, allowable loadings are in the neighborhood of one SIL. This suggests that the SIL in kilowatts of a line can be used as the base kilovolt-amperes of the line. Likewise the surge impedance can be considered to be the base ohmic impedance of the line.

The line constants can be put on this per-unit basis by dividing the *B* constant by Z_0 and multiplying the *C* constant by Z_0. Thus, a set of constants is produced which is dependent upon line length and r/x ratio. Curves are plotted with r/x as a parameter showing the variation of the line constants with line length. These curves can be used to determine the 60-cycle characteristics of any practical copper, stranded copper, or steel-reinforced aluminum cable lines, regardless of conductor size, spacing, operating voltage, or surge impedance.

REFERENCE

1. Electrical Transmission and Distribution Reference Book (fourth edition). Westinghouse Electric Corporation, East Pittsburgh, Pa., 1950.

Digest of paper 51-26, "A Per-Unit Interpretation of Transmission-Line Constants," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. Published in AIEE *Transactions*, volume 70, part I, 1951, pages 194–201.

D. J. Povejsil and **A. A. Johnson** are both with the Westinghouse Electric Corporation, East Pittsburgh, Pa.

A Study of Helium Gas Clean-up in an Electric Arc Discharge

M. J. REDDAN   G. F. ROUSE

Gas discharge tubes with movable cylindrical probes have been used to determine the clean-up which results from the bombardment of a tantalum surface by positive helium ions. Data agree closely with earlier work using wire probes, and it has been possible to recover between 70 and 85 per cent of the trapped gas.

GAS CLEAN-UP, or the gradual disappearance of the filler gas in an electric discharge, has been observed by many investigators. From a paper by E. Pietsch[1] published in 1926 and listing 169 references, we can draw some interesting conclusions regarding work performed before that date. In evaluating the data, several facts should be recalled: most of the articles were published before the announcement of Langmuir's probe theory; most of the work was carried out in chemically active gases; and finally, much of the work was performed with poor vacuum techniques. Nevertheless, several areas of agreement may be noted:

1. It was generally agreed that cathode sputtering strongly influences clean-up. In many cases clean-up and the onset of sputtering were found to appear at the same critical potential.
2. Practically no absorption into the anode was observed.
3. Noble gases are absorbed far less readily than are molecular gases.
4. Gas absorption was sometimes explained by recourse to the supposition that various unstable chemical compounds were formed. Even "helides" were reported.
5. Absorption into the envelope of the discharge tube was reported, and frequently it was claimed that the amount absorbed was not dependent on the type of gas, wall material, or wall potential.

Since this earlier work was done under a wide range of experimental conditions, the failure to deduce from it any consistent explanation of gas absorption is not surprising.

About 1936, a great deal of information was contained in a series of papers published in Germany by Alterthum, Lompe, and Seeliger.[2,3] Their work was simplified by being restricted to the noble gases. They worked with an a-c glow discharge in cylindrical glass tubes in which the electrodes were open-ended sheet-iron cylinders. The use of open cylindrical electrodes gives the advantage of almost constant cathode fall over a wide range of currents and pressures. A summary of their results is of considerable interest.

They found the following facts for neon gas: 1. over a pressure range from a few tenths of a millimeter to about 3 millimeters, the absorption rate is independent of the pressure; however, at higher pressures the rate falls off; 2. the absorption rate is proportional to the discharge current; 3. at the current employed (100 milliamperes) the rate is independent of the shape and size of the discharge tube; 4. the absorption rate is not influenced even by excessive sputtering. By conducting separate experiments with a d-c glow discharge, it was found that absorption was taking place in the cathode. Recovery of about 30 per cent of the trapped gas was accomplished by heating the cathode inductively. An important observation was that by creating a high cathode fall either through operation at low pressures (below 0.2 millimeter), or through the use of closed-end electrodes, the absorption rate was increased by a factor of 4. This leads to the attractive explanation that absorption results from the fact that ions are driven into the cathode under the accelerating field of the cathode fall. A direct estimate of the dependence of such clean-up on ion energy, however, cannot be obtained from these data for the following reasons:

1. The energy of the ions cannot be determined since multiple collisions take place in the cathode-fall region.
2. The proportion of current at the cathode carried by ions must be known to determine the number of ions striking.

It is now generally thought that clean-up can result from the bombardment of negatively charged electrodes by ions present in the discharge. Tube engineers have long been aware of the importance of this clean-up problem and have developed methods for minimizing its effects. For example, D. V. Edwards and E. K. Smith[4] described a method of minimizing clean-up by the use of "cushioning" circuits which permit deionization to occur while the inverse anode voltage is low. D. E. Marshall and C. L. Shackelford in a recent paper[5] discussed the influence of the commutation factor rating on the design of such "cushioning" or "snubbing" circuits. Also, A. W. Coolidge, Jr., has described[6] a line of thyratrons in which close spacing of the electrodes permits a high filling pressure, and a well-

Full text of paper 51-353, "Clean-up of Helium Gas in an Arc Discharge," recommended by the AIEE Committee on Electronics and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

M. J. Reddan and **G. F. Rouse** are with the National Bureau of Standards, Washington, D. C.

This is an interim report on the gas clean-up program initiated at the National Bureau of Standards by Dr. J. E. White, to whom the authors express appreciation for many valuable discussions and suggestions. The primary object of these studies is the discovery of information on gas clean-up which will be of value to tube designers.

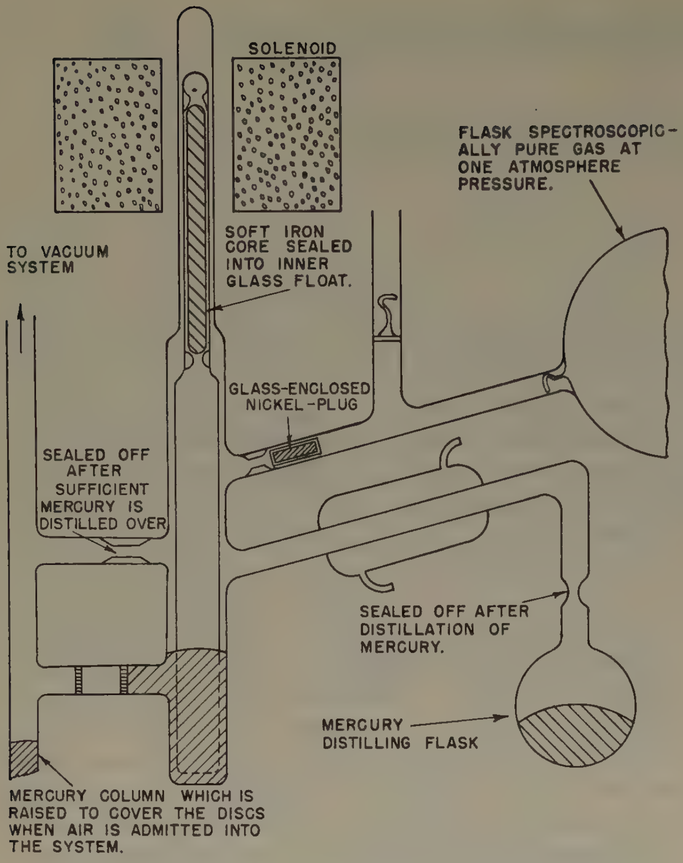

Figure 1. Apparatus for admitting gas to the vacuum system

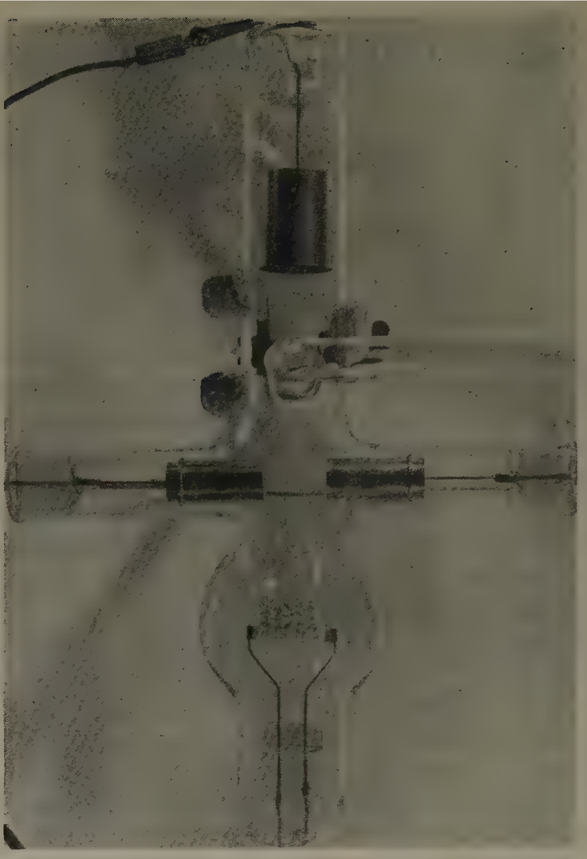

Figure 3. A gas discharge tube containing a wire probe

shielded anode exposes a minimum area to ion bombardment during inverse voltage conditions.

EXPERIMENTAL APPARATUS AND METHODS

Experimental equipment was designed to obtain data on controlled clean-up which results from the bombardment of a tantalum surface by positive helium ions. Since there was reason to believe that other important clean-up effects would be present, it was necessary to carry out the experiment in a manner which made the required correction possible.

The problem of obtaining pure gas received particular attention. Spectroscopically pure gas was obtained from commercial sources. To attain even greater purity, a getter device was employed during the initial work. This consisted of strands of zirconium and tantalum wire which were heated in the presence of the gas to remove from the gas any minute traces of nonnoble gases. It was subsequently discovered that the very small amounts of impurity present in the unopened flask of pure gas were not sufficient to affect the experimental results. In later work, a check on the gas purity was achieved by sealing off small samples for mass-spectrometer analysis. This was supplemented by a continuous visual observation of the arc spectrum in a spectroscope.

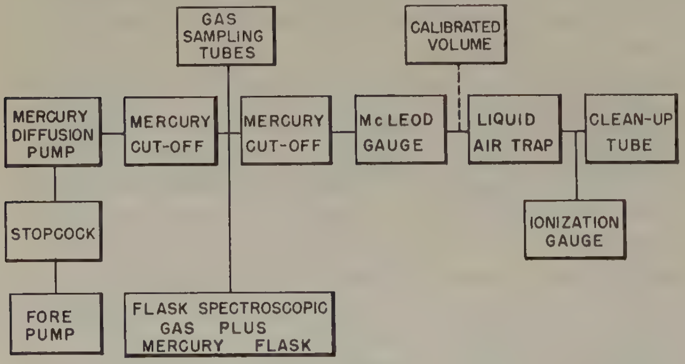

Figure 2. Block diagram of the experimental system

To assure that the original purity was maintained during admission of filling gas to the tube, several schemes were tried. A device for introducing gas which avoids entirely the use of stopcocks finally was developed. A detailed view of this is shown in Figure 1. When this device is first attached to the vacuum system, the seal-off constriction is open, the gas flask is unopened, and the mercury shown at the right of the fritted disks is still in the distillation flask.

All parts of the valve structure, other than the distilling flask, can then be outgassed thoroughly by baking at about 425 degrees centigrade. When the baking is completed, mercury is distilled over slowly until the right fritted disk is completely covered. Then the seal-off constriction directly above the fritted disks is closed, the mercury flask is sealed off the system, and the gas flask is opened. Gas now can be admitted to the system by raising the float and uncovering a small portion of the fritted disk. To maintain the purity of the gas when it becomes necessary to admit air to the vacuum system, the mercury column at

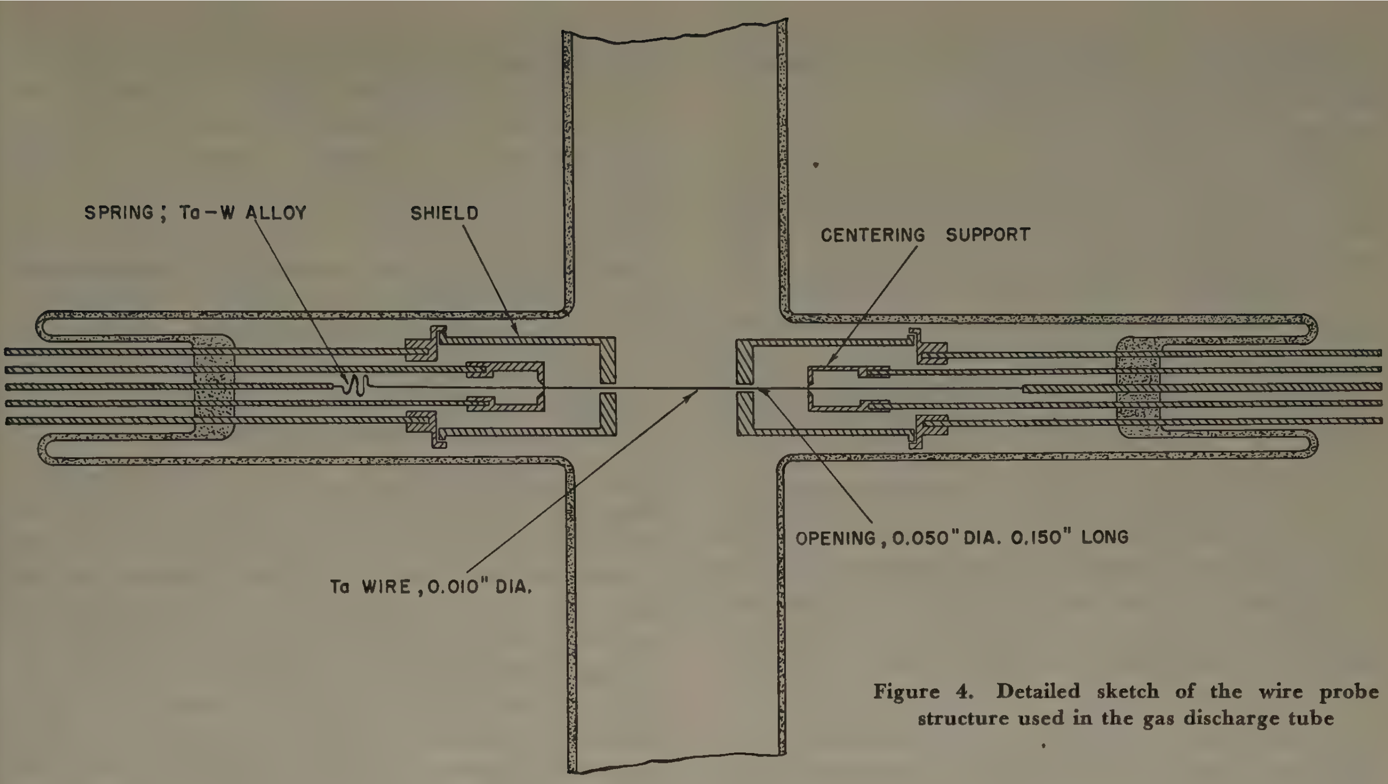

Figure 4. Detailed sketch of the wire probe structure used in the gas discharge tube

the extreme left of the figure is raised to cover the fritted disk on the left.

A block diagram of the vacuum system employed is shown in Figure 2. No stopcocks were used in that portion of the system in which clean-up takes place. Instead, barometrically operated cutoffs were employed.

Data have been obtained on discharge tubes of two types, the essential difference between them being in the design of the probe structure. The features of the cathode and anode structures common to both types are shown in Figure 3. The oxide cathode, a commercial one having a nickel mesh base, has an area of approximately 30 square centimeters. The hollow cylindrical anode is made of grade-A nickel. Figure 3 also pictures one type of probe structure, the details of which are shown in Figure 4.

In this structure the probe is a tantalum wire, 0.010 inch in diameter, mounted so that current can be passed through it for purposes of outgassing. Its tension is maintained by a tantalum-tungsten alloy ribbon-type spring (0.002 by 0.150 inch). The action of this spring, in conjunction with the centering action of the molybdenum spacers, maintains an accurate positioning of the wire. Even at temperatures in excess of 2,000 degrees centigrade the positioning is satisfactory. The nickel shields allow only a chosen fraction of the probe wire to be exposed to the discharge plasma. The cylindrical openings in the ends of the shields through which the probe wire passes are 0.050 inch in diameter and 0.150 inch long. The opening between the wire and the shield is so small as to reduce to a negligible amount the migration of ions toward shielded parts of the probe. The shields are outgassed readily by inductive heating.

The other type of probe structure is shown in Figure 5. The probe is an open-ended cylinder made of 0.005-inch tantalum. Its diameter is 1.55 inches and its length 1.55 inches. By means of a magnetically controlled mechanism, not shown in the sketch, the probe cylinder can be placed in either of the two positions indicated in the figure. In the lower (number 2) position the cylinder rests on tungsten wire supports through which electric connection is made. The clearance between the probe cylinder and the wall of the glass envelope is small enough

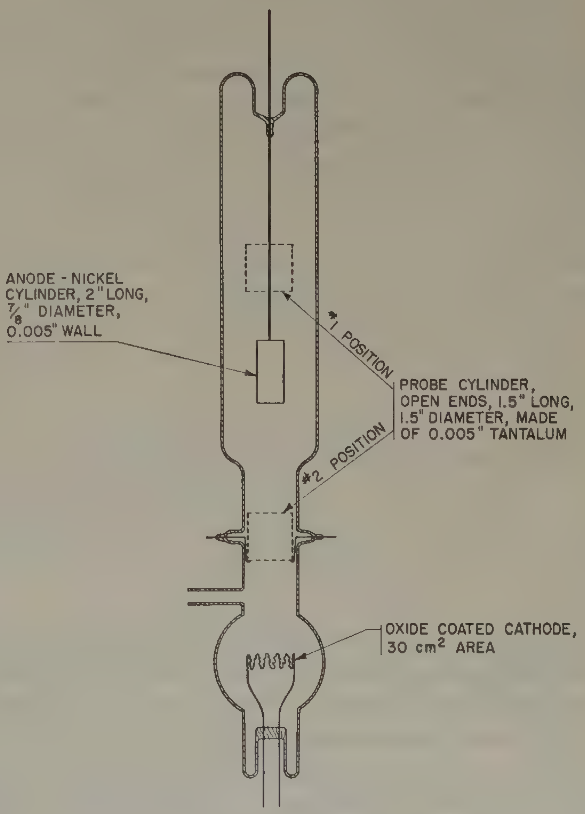

Figure 5. Gas discharge tube containing a cylindrical probe

(approximately 1 millimeter) to prevent migration of ions behind the probe. When the probe is in the number 1 position it can be heated to a very high temperature without endangering the glass envelope.

Excessive heating of the probe wire or the probe cylinder by ion bombardment was avoided by applying negative pulses of about 10 milliseconds' duration with a repetition rate of 10 per second.

The calculation of the number of disappearing helium atoms is based on measurements of a pressure drop occurring in the known volume of the system. This volume is determined by observing pressure drops which occur when the system is opened to an accurately calibrated standard volume.

ASSOCIATED SOURCES OF GAS DISAPPEARANCE

IN AN EXPERIMENTAL study of the conditions governing clean-up into a probe, it naturally would be desirable to eliminate all other sources of clean-up. Since their complete elimination was not possible, these effects were reduced in magnitude and proper allowance made for them:

Leakage Through the Tube Wall. It was realized that a loss of gas might occur which would be completely independent of the presence of a discharge in the tube. Neutral atoms of gas having only thermal energy might diffuse into or through the glass wall of the tube. Data exist[7] which make it possible to calculate the drop in pressure to be expected as a result of helium diffusion through the Pyrex envelope. Assuming the envelope temperature to be 250 degrees centigrade and the helium pressure as 0.2 millimeter of mercury, the calculated pressure drop in a system having an approximate volume of 2.0 liters is 6×10^{-3} micron per hour. A simple test was made to check this conclusion. A Pyrex glass bulb having a wall area approximately equal to that of the experimental tube was evacuated and degassed thoroughly, after which it was filled with helium to a pressure of about 0.2 millimeter. Heating the bulb to 350 degrees centigrade for 22 hours resulted in a negligible change in pressure.

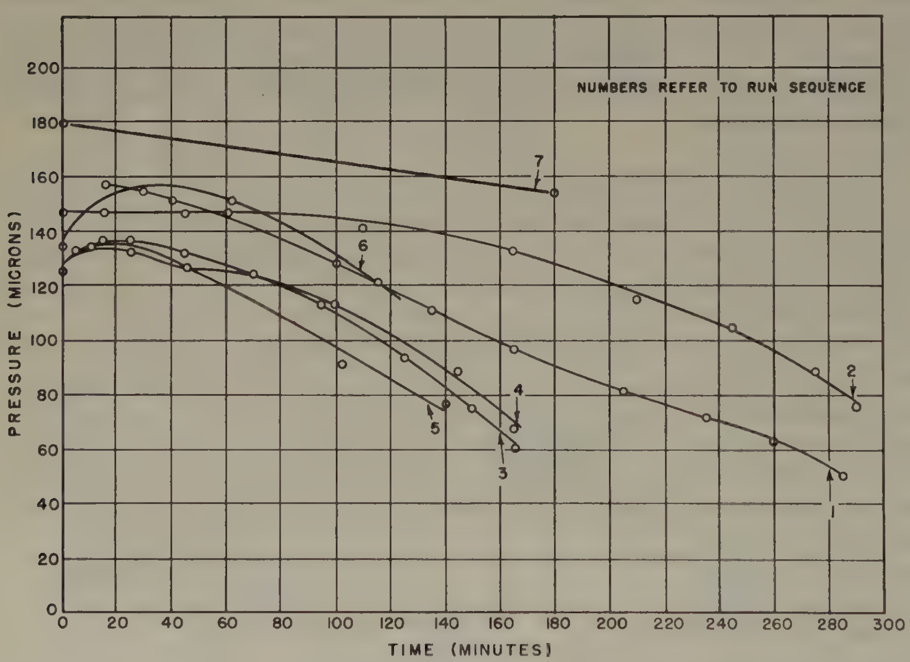

Figure 6. Data illustrating a case of abnormal cathode clean-up

Clean-up Into the Anode or Shields. Since the anode acquires the highest positive potential in the tube, clean-up of positive ions into it is not to be expected. This has been confirmed repeatedly by a thorough inductive heating. The nickel shields in the wire type probe structure are operated at a potential which assures that current to the shields is due almost entirely to electrons.

Clean-up Into the Cathode. Of the various associated effects which must be considered, clean-up of gas into the cathode is perhaps the most important. One fact which has been established definitely is that clean-up into the cathode is dependent upon arc drop. Actually, a more exact description would be to say that the effect is dependent upon cathode fall, but since the latter was not measured directly, a description in terms of arc drop must suffice. In a tube having a cathode of high quality, the gas pressure can be controlled so as to maintain the arc drop at a value for which the self clean-up rate is approximately 10^{-2} micron per minute. Anything which causes the arc drop to rise, as, for instance, too great a drop in pressure or poisoning of the cathode, causes an increase in the self clean-up rate. For example, it was deduced from a series of observations that on an average an increase of 13 volts in arc drop increases the self clean-up rate by a factor of approximately 100.

The effect of increased arc drop on self clean-up is illustrated strikingly by data taken on a tube in which the cathode had low emission and which operated with an arc drop about 15 volts higher than that in a similar tube having a good cathode. These data are plotted in Figure 6. During the initial run, to which curve 1 applies, the pressure dropped from 158 microns to 50 microns. Since it was thought best not to operate the tube at a pressure below 50 microns, fresh gas was added. The data from which curve 2 was plotted were taken then. This procedure was repeated a total of 7 times. It is interesting to note that the total gas which was absorbed in about 22 hours is approximately equivalent to that in a liter flask at 600 microns' pressure. It is also interesting to note that there is little indication that the process was approaching saturation. The initial rise which appears in some of the curves is accounted for by an increase in tube temperature.

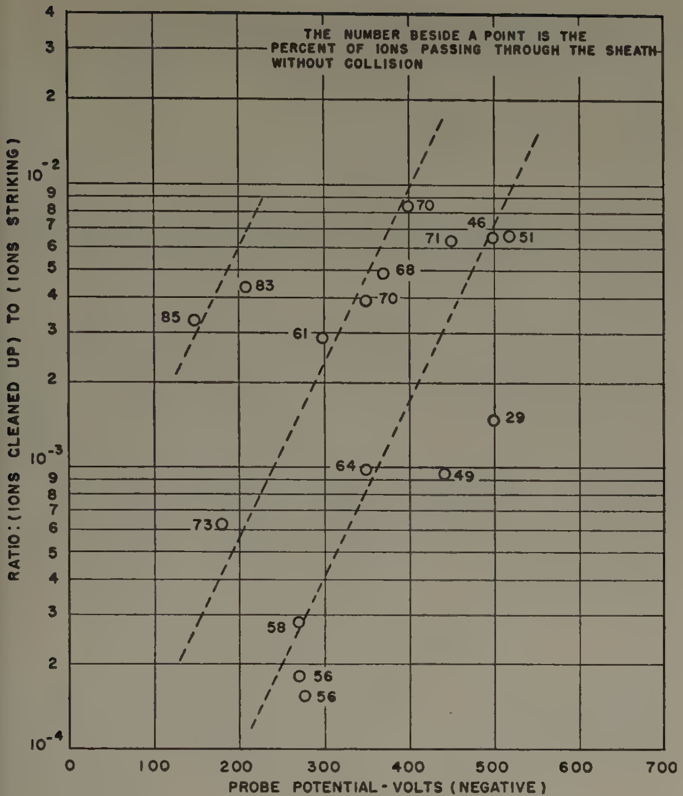

Figure 7. Dependence of clean-up upon the number and energy of impacting ions—wire probe

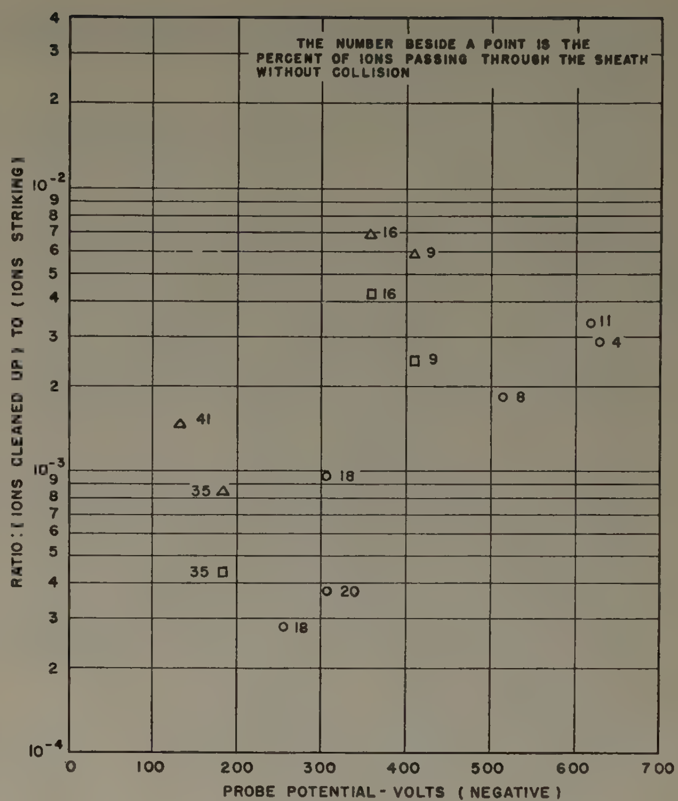

Figure 8. Dependence of clean-up upon the number and energy of impacting ions—cylindrical probe

The self clean-up rates just mentioned contrast markedly with the almost complete lack of clean-up exhibited by many commercial tubes which operate with a much lower arc drop and which do not contain helium gas.

Clean-Up Into a Sputtered Deposit. Comments made at the beginning of this article emphasize that a wide divergence of opinion exists as to the role played by sputtering in gas clean-up. Under certain conditions a certain amount of sputtering has been unavoidable. In the case of the wire probe the glass surfaces adjacent to the probe structure showed no visible evidence of a sputtered layer. However, in the case of the cylindrical probe a band of sputtered material appeared on the glass near each end of the probe after several hours of operation at negative probe voltages in the range of 400 to 600 volts. Some data on the effects produced by these sputtered bands will appear in the section dealing with recovery of gas.

DETERMINATION OF PROBE CLEAN-UP

The first step in a determination of probe clean-up was to clean and degas the tantalum probe thoroughly. This was accomplished by maintaining its temperature at approximately 2,000 degrees centigrade for several minutes in a vacuum of about 10^{-6} millimeter of mercury. Following this clean-up the tube was filled with helium to a desired pressure.

Since all the associated clean-up effects discussed so far may be present unavoidably during operation of the tube, some method of correcting for them was necessary. A correction factor was determined by observing the rate of clean-up when the conditions of operation limited the ion probe current to a negligible value. This rate of clean-up will be referred to as self clean-up. Probe clean-up always occurred at a rate at least ten times as great as that for self clean-up. Therefore errors existing in measured values of self clean-up did not have an unduly large effect upon the corrected values of probe clean-up.

The tube then was operated with a pulsed negative potential on the probe, that is, with an ion current to the probe, and the new rate of clean-up was established. In most instances this was followed by a recheck of the self clean-up rate. Net clean-up into the probe then was obtained by making the proper correction for self clean-up.

The quantity of gas disappearing was calculated from pressure readings which were recorded at the beginning and end of a test when all parts of the tube were at room temperature.

It is of great practical interest to know what fraction of the ions which strike the probe surface at a given voltage are trapped. This information is plotted in Figures 7 and 8. The numerator of the ratio plotted as ordinate was derived from the net pressure change due to probe clean-up, while the denominator was derived from conversion of values of peak probe current to fundamental charge units. The latter calculation does not take into account that part of the probe current due to electrons ejected from the probe by ion impact. Direct experimental data which might be used to correct the probe current for this effect are not available. An indication of the probable magnitude of the correction might be obtained by using data for impact of helium ions on molybdenum.[8] However, from

an application viewpoint, the data are probably of greater interest in the form presented.

Although the points plotted in Figure 7 may appear to be distributed randomly over the voltage range, it is possible to attach significance to the position of each point. This may be done by selecting as a parameter the ratio R of ionic mean free path to sheath thickness around the probe wire. The first of these can be calculated by means of simple kinetic theory formulas and the sheath thickness is obtained by use of the appropriate space charge formula. The fraction of positive ions which pass through the sheath without collision is given by $\epsilon^{-1/R}$. Average values for this fraction, expressed in per cent, appear in Figures 7 and 8 adjacent to the plotted points.

In the case of the wire probe (Figure 7) the percentage values vary from about 40 to 85 per cent. Dash lines have been drawn to suggest groupings of the points. It becomes evident from a study of Figure 7 that the number of ions cleaned up is a strong function of probe voltage. However, it is evident also that this number is dependent upon other factors which determine the fraction of ions passing through the sheath without collision.

In the case of the cylindrical probe (Figure 8) the percentage values vary from about 4 to 40 per cent. It will be observed that the number of ions cleaned up depends upon voltage in a manner quite similar to that shown in Figure 7. A striking feature of these data is that the clean-up rate is essentially the same for both probes even though the number of ions reaching the cylindrical probe without suffering collision in the sheath is relatively very small.

RECOVERY OF CLEANED-UP GAS

THE FACT THAT a clean-up of gas is associated with the flow of positive ions to a negatively charged metal surface has been established definitely. Although this effect is well supported by experimental data, it was considered worth while to attempt a reversal of the clean-up process and in this way obtain evidence that gas trapped in the probes is primarily responsible for a pressure decrease.

Recovery in the tube having a wire probe was accomplished by the following methods:

1. Heating of the wire. The wire was heated by Joule heat to 2,000 degrees centigrade. In four recent tubes this has yielded percentages of recovery ranging from 5 to 22 per cent of the net probe clean-up.
2. Recovery from the cathode has been accomplished by glowing the cathode at its normal operating temperature of 825 degrees centigrade with the tube dark. This procedure has recovered from 11 to 54 per cent of the gas disappearing during self clean-up.
3. The probe shields and the anode were outgassed by inductive heating to about 800 degrees centigrade. No significant amounts of gas were recovered in this way.
4. Finally, the tube envelopes were oven-baked at about 400 degrees centigrade. Various amounts of gas were recovered, ranging from 8 to 31 per cent of the total amount of gas disappearing due to all sources of clean-up.

Recovery in the tube having a cylindrical probe was accomplished by degassing of the probe cylinder by inductive heating (position number 1) after each clean-up run. While the tube was relatively new and free from any sputtered deposit, degassing the cylinder accounted for 70 per cent or more of the cleaned-up gas. As the sputtered bands near the ends of the probe cylinder became increasingly opaque percentage recovery from the probe declined.

Following each of the last four runs recorded, the sputtered region of the envelope was baked for several hours at 350 degrees centigrade. In these cases total recovery was still about 70 per cent but approximately half of the recovery resulted from baking the sputtered area. The four values of the clean-up ratio indicated by triangles in Figure 8 are based on total observed clean-up. Those values indicated by squares are based on gas recovered from the probe.

CONCLUDING REMARKS

THE FACT THAT only a small proportion of the cleaned-up gas could be recovered from the wire probe has no satisfactory explanation. A means of freeing any helium not already driven off by heating was to disintegrate the wire completely. Consequently a probe wire was sputtered away completely in a mercury vapor discharge, the sputtered material passing over to the wall of the tube. A directly observable result was a pressure increase of 1 micron. Assuming that the gas which disappears during a probe clean-up is held in the wire, the 1-micron increase in pressure is only a small fraction of that which might have been expected.

It has been assumed in the preceding work that clean-up occurs only during the initial impact of an ion with the surface. However, in view of the significant amounts of gas recoverable from the area of the tube wall on which metal is sputtered, it may be that rebounding atoms play an important role. It is conceivable that some of the impacting ions are reflected as neutral atoms which in turn are trapped as they strike some near-by surface. An effort will be made to check this possibility in future work.

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Relay Protection of 33-Kv Tie Feeders

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UTILITY TIE FEEDERS to large industrial customers sometimes present unusual relaying problems. The relaying on the 33-kv 60-cycle tie feeders between Riverside Substation of the Consolidated Gas Electric Light and Power Company of Baltimore (Md.) and the Sparrows Point Plant (Md.) of the Bethlehem Steel Company includes several unusual features.

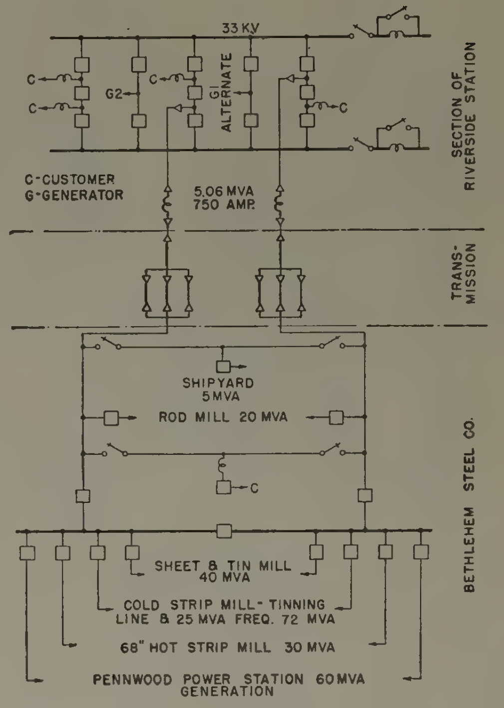
Figure 1 shows the magnitude of the connected load in this interconnection. The customer tap in the steel company area is for a small unrelated service. In addition to the 60-cycle system, the steel company has 25-cycle service. The integrated plant load is about 150 megavolt-amperes with a peak load of 200 megavolt-amperes. Transmission circuits are 500,000-circular-mil bare copper conductors carried on wood poles and three 350,000-circular-mil submarine cables. The circuits have three tapped loads connected to them before they reach the steel company bus. A 33-kv bus tie circuit breaker is shown and other 33-kv ties are possible. None of these are closed normally. Several 6.6-kv ties are maintained between the 33-kv circuits in the steel company area. These are through 33-kv delta to 6.6-kv Y-grounded transformer banks and consequently furnish no zero-sequence current for the 33-kv circuits. At Pennwood one 30-megavolt-ampere unit is operated normally in parallel with each 33-kv circuit and the unit transformers furnish a source of zero-sequence current when they are in service.

Modified pilot-wire relaying with automatic supervision and transfer tripping furnishes the primary protection for each circuit. The pilot-wire terminals are located at Riverside and at the circuit breaker feeding the main steel company area. The relays used have their operating coils in series with the pilot wires and can be prevented from operating by opening the pilot wires at any point. This characteristic is utilized to prevent operation of the pilot-wire relays for faults in the shipyard, rod mill, or on the customer tap. At each of these locations, instantaneous overcurrent relays are connected to open the pilot wires for through faults. As a further check against false operation due to the loads connected within the pilot-wire zone, instantaneous overcurrent threshhold or fault-detector relays are used at each pilot-wire terminal. These have their contacts connected in series with the contacts of the pilot-wire relays and must operate in conjunction with the pilot-wire relays to trip the circuit breakers.

Induction-type definite-time overcurrent relays with instantaneous attachments are used at Riverside for backup to the pilot-wire relays and the steel company main circuit breakers. They are not affected by the relays at the various taps that prevent operation of the pilot-wire relays.

The pilot-wire relay and the backup overcurrent relays are each connected to transmit a transfer trip signal to the corresponding steel company circuit breakers for any relay

Figure 1. Primary connections in 1950



operations at Riverside. Between Riverside and the steel company pilot-wire terminal, the standard supervisory relays used for the pilot wires also furnish the transfer trip feature. At the rod mill one of the 6.6-kv ties between the 33-kv lines is in service and as a result a transfer trip signal is needed here also. This is taken care of on a separate pair of telephone wires using polarized tripping with dry rectifiers to determine the circuit breaker to be tripped.

Benefits realized from this system of relaying are:

1. Essentially instantaneous differential protection is provided for the feeders even though they are tapped at three intermediate points. This protection was required to minimize damage and decrease system disturbances caused by faults on these feeders.

2. Overload protection is provided based on the emergency carrying capacity of these tie feeders. The loss of one feeder carrying a heavy load could overload seriously the remaining feeder without operating the backup overcurrent relays.

3. Transfer tripping is provided. This protection was needed because of the possible operation of the steel company system without a source of zero-sequence current.

4. Backup overcurrent protection is provided. This protection is utilized to back up the pilot-wire relays and to reach into the steel company 33-kv system.

Digest of paper 51-357, "Relay Protection of 33-Kv Tie Feeders to a Large Industrial Customer," recommended by the AIEE Committee on Industrial Power Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Not scheduled for publication in AIEE *Transactions*.

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The Selenium Rectifier for Contact Protection

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A VOLTAGE SURGE SUPPRESSOR is described comprising selenium rectifier cells connected in series (in opposed relation) whereby the resulting resistance is high at low voltages and low at high voltages.

This combination of rectifiers when used for electric contact protection results in an excellent arc-suppressing device which does not affect materially the release time of the shunted electromagnet.

The conventional method of using the selenium rectifier as a spark suppressor is shown in Figure 1 (option *X*). When the contacts at *A* are closed, there will be little current flowing through the rectifier due to its high reverse resistance. When the contacts at *A* are separated, the induced electromotive force will maintain the current flow through the coil in the same direction, and the open contacts will be shunted by the low forward resistance of the rectifier. This low-resistance shunt will eliminate arcing at the contacts but has the effect of prolonging the release time of the electromagnet. The increase of the voltage across the open contacts is directly proportional to the rectifier resistance. An increase in rectifier resistance will reduce the release time but will increase arcing.

This conflict between arc suppression and required release time may be resolved by the introduction of a voltage-dependent resistance. If the resistance is low at high voltage, arcing will be eliminated; if the resistance is high at low voltage, improved release time will result. Such an element is obtained when rectifier number 2 is added to the circuit as shown in Figure 1 (option *Y*).

The selenium rectifiers used for protection of telephone relay contacts basically are combinations of 9/32-inch diameter cells. The reverse resistance versus voltage characteristic of the 9/32-inch diameter cells is of considerable interest, particularly at voltages that exceed the d-c rating of the cells. In order to simulate load conditions, the rectifiers were stressed with a voltage lasting 8 milliseconds. Figure 2 illustrates the reverse resistance-voltage characteristic for the rectifier combinations before and after life test. Curve *A* is typical for an unaged 2-cell unit, and curve *B* shows the resistance characteristic after 50,000,000 operations of a telephone relay as the load over a period of 6 months. The rectifier represented by curve *B* was connected in the life-test circuit in the same way as rectifier number 2 in Figure 1. The increase in reverse resistance shown in curve *B* is related to the forming process. Higher reverse voltages have the effect of raising the back resistance, and prevent the rectifiers from deteriorating when the current flows only in one direction.

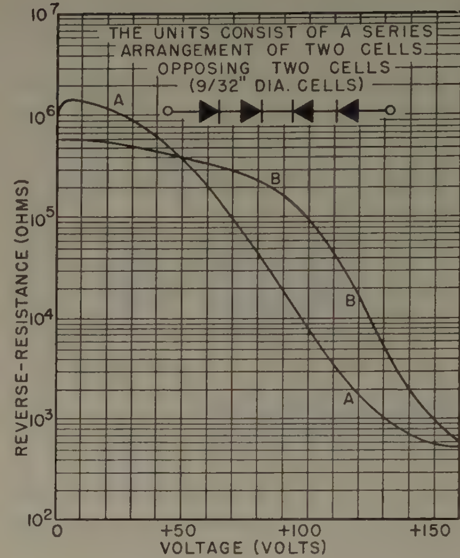

Figure 2. Reverse resistance versus voltage characteristics of spark suppression units

Rectifier breakdown, that is, the tendency for the forward and reverse resistance to equalize, always is associated with excessive temperature. If the high-voltage stress is not applied long enough for the temperature to rise excessively, and the duty cycle is not excessive, the rectifier will not be injured.

Contact erosion in the sense that metal is transferred from one contact to the mating contact seems to be eliminated. Metal is lost equally from both contacts. The characteristic build-up on one contact and the crater in the other, associated with resistor-capacitor contact protectors, is not present. This is important from the standpoint of reducing snagging or mechanical locking.

Satisfactory release time or rate of decay of current in the controlled electromagnet is obtained by the addition of rectifier number 2 as shown in Figure 1. The rectifier combination compares very favorably with other known methods of contact protection with respect to peak voltage and timing characteristics.

Selenium rectifiers are inexpensive and are known to have an almost indefinite life. The contact protection units are simple to mount and, furthermore, it is not necessary to observe polarity when wiring. This, together with their dependability over extended periods without attention, makes them most desirable circuit elements.

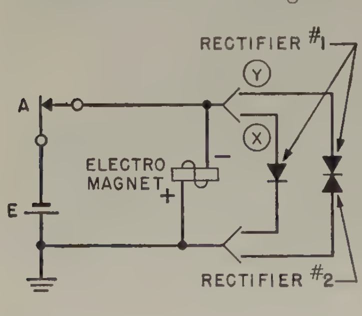

Figure 1. Methods of using selenium rectifiers for contact protection

Digest of paper 51-352, "Investigation of the Selenium Rectifier for Contact Protection," recommended by the AIEE Committee on Communication Switching Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Simplified Measurement of Subtransient Reactances in Synchronous Machines

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This radical modification in salient-pole synchronous machine testing avoids the many serious mechanical and electrical difficulties of present methods of measuring subtransient and negative-sequence reactances. No special equipment is required, and test results have proved the method to be reliable.

THE NECESSITY OF analyzing and predicting the behavior of synchronous machines in normal operation and under sudden fault conditions becomes ever more important with the increasing extension and complication in interconnected power networks and in studies of stability of such systems. To determine the operating characteristics of synchronous generators and thus predict their behavior, actual test measurements on such generators must be taken and certain constants extracted to be used later where they apply in a synthesis of calculated performance for given operating conditions. These constants are known as the "synchronous machine quantities," some of which are of interest chiefly for transient system conditions.

Specifications and contracts for large synchronous generators state "calculated values" for the direct-axis and quadrature-axis subtransient reactances, X_d'' and X_q'', and for negative sequence reactance, X_2. The calculated ratio of these subtransient reactances, X_q''/X_d'', also is stated, this value being considered important as indicating the effectiveness of damper windings in suppressing transient voltages in stator and rotor windings when unsymmetrical faults occur on the power system.

The subtransient reactance of a synchronous generator is that reactance which, coupled vectorially with the relatively negligible resistance, determines the initial symmetrical value of current that will flow in the stator winding upon sudden application of a short circuit at its terminals when the machine is running at normal rated voltage and without load. The short-circuit current may be resolved into direct-axis and quadrature-axis components. The subtransient reactance also is resolved into similar components, each applying to determine the value of the respective component in initial short-circuit or fault current. The components of this reactance are known as the direct-axis and quadrature-axis subtransient reactances.

Negative sequence reactance may be taken as the arithmetical average of the direct-axis and quadrature-axis subtransient reactances, usually calculated between stator terminal and neutral.

MEASUREMENT OF SUBTRANSIENT REACTANCES

THE AIEE TEST CODE for Synchronous Machines[1] approves several special tests for finding the various individual synchronous machine quantities. Attention here is drawn to Method 3, Section 1.865, for determining the direct-axis subtransient reactance of a 3-phase generator by measurement of applied single-phase stator impedance voltage and stator current, with the rotor stationary in that position where a given stator current induces the maximum alternating current in the rotor winding when it is short-circuited across the collector rings. Actually, impedance is measured but the resistance component is considered as being so small that it is negligible and the results are taken as measurement of subtransient reactance only. One-half of the reactance thus measured is the direct-axis subtransient reactance of the generator from stator terminal to neutral, in ohms.

This Test Code does not suggest a stationary-rotor method of determining quadrature-axis subtransient reactance of generators but the Westinghouse Transmission and Distribution Reference Book[2] recommends a method, the same as the Test Code Method 3 for the direct-axis subtransient reactance, except that for the quadrature-axis measurement the rotor is placed in a position where there is no induced current in its windings, no matter what value of stator current is used. One-half of the reactance measured in this case is the quadrature-axis subtransient reactance from terminal to neutral, in ohms.

Stationary-rotor tests for measurement of both subtransient reactances have been described, with emphasis on the necessity of using low stator current to avoid rotor heating.[3] For salient-pole machines with dampers the direct-axis subtransient reactance measured at rated current is very nearly the saturated value of X_d'' and the quadrature-axis subtransient reactance measured at low current values equals approximately the saturated value of X_q''. In testing generators by the new method of measurement, the authors used up to 40 to 50 per cent of rated stator currents, and in a few cases used full rated current.

These tests, with the rotor in special positions, may be convenient and satisfactory for very small machines but when large vertical generators driven by water turbines are

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The authors are deeply indebted to the Canadian General Electric Company, the Canadian Westinghouse Company, and the English Electric Company for their interest and valued assistance in running these special tests on their new synchronous generators and motors to prove the merits of these test methods by measurement on actual machines of different designs and ratings.

to be tested in this way, it may be necessary to uncouple the turbine from the generator and then to move the rotor several times through small angles to find the particular two positions desired. Such small movements of the large rotors introduce considerable difficulty, not only in starting the motion but also in preventing the rotor from gliding too far. Furthermore, very many movements and measurements may be necessary to be certain that maximum and minimum rotor current positions have been found.

When these tests were made on a 22,500-kva 60-cycle generator after installation, the methods were modified by marking off one pole span on the stator frame and taking a series of readings for several rotor positions within this span of movement. The subtransient reactances, between terminals, for these positions were plotted and the points appeared to be following a sine wave displaced from the zero line by considerably more than its amplitude, Figure 1*A*. Thus, there were two components, a constant offset or displacement, K, and a sine wave of amplitude, M, having 1 cycle per pole span. The maximum and minimum values, namely the quadrature-axis and direct-axis subtransient reactances, between terminals, were determined from the plotted results. Their ratio gave the important quantity, X_q''/X_d''. The subtransient reactances from terminal to neutral were taken as one-half of the measured values.

In later acceptance tests of a 23,500-kva 60-cycle machine at another generating station, the time necessary to uncouple and recouple the turbine and to make the

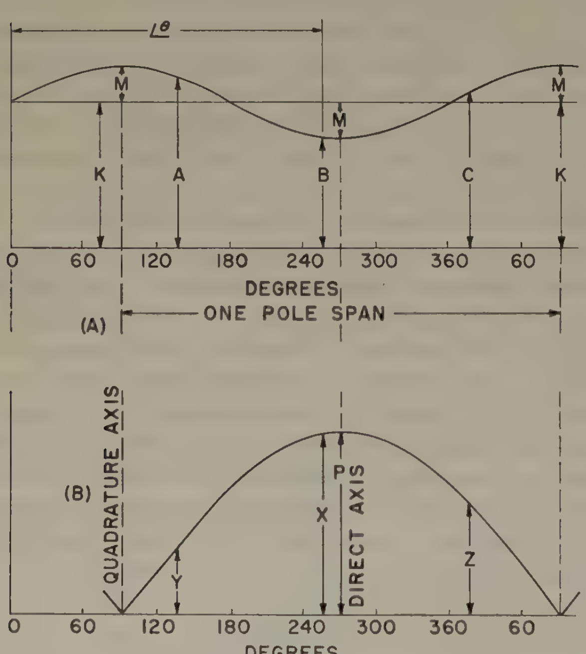

Figure 1. (A) The displaced sine wave of subtransient reactance between stator terminals. One cycle per pole span; M = amplitude of wave; K = displacement or offset of wave; A, B, C = any set of three values spaced 120 degrees apart. (B) The fully rectified sine wave of induced rotor current, rms values. One half-cycle per pole span; P = maximum possible value; X, Y, Z = values corresponding to positions of A, B, and C, but not necessarily in the same order. The highest of the three values must be designated X for insertion in the formula to calculate the maximum possible value

tests as described could not be spared, so subtransient reactance tests had to be waived in this case. This information has now been obtained, however, by the new method of test.

NEW 3-READING METHOD OF MEASUREMENT

As the uncoupling and recoupling of the turbine require much labor and many hours to complete, and also the movement of the rotor by small angles to special positions is difficult and needs several riggers and considerable tackle, the following simplified method of test has been developed to circumvent these problems, and has been applied in several instances — on generators rated from 100 kva to 50,000 kva — with great facility and remarkable success.

By this method, the turbine is not uncoupled and the rotor is stationary in any position whatsoever. With the rotor winding short-circuited, preferably through a current transformer or ammeter across the collector rings, and with the lead disconnected from any one stator terminal, single-phase voltage is applied to the remaining two terminals. Stator voltage and current are read and recorded, and also rotor current, though this is not necessary in this test. Single-phase voltage then is applied in turn to each of the other two possible pairs of stator terminals, the respective third terminal being open, and voltage and currents read again in each case, as before.

The results of these measurements give three values of stator voltage-current ratios, that is, subtransient reactances between stator terminals, corresponding to three different positions of the rotor. These ratios may be designated as quantities A, B, and C. They may be measured or lettered in any order desired, without even keeping track of the sequence, and from these results, on the basis of the variation being a sine wave, as previously explained and now quite well proven, the desired quantities may be calculated readily by the following formulas.

The constant offset or displacement component K is

$$K=\frac{A+B+C}{3}$$

The amplitude M of the sine wave component, measured from its offset zero line, is

$$M=\sqrt{(B-K)^2+\frac{(C-A)^2}{3}}$$

The determination of the value of M is very much simplified if, for a given rotor position, any two of the three ratios, A, B, or C, are equal. In such case, M is the arithmetic difference between K and the third, or unequal, ratio.

If desired, the phase position θ of measurement B, in degrees from the zero value of the sine wave (where increasing positively), can be determined as follows

$$\tan\theta=\frac{\sqrt{3}(B-K)}{C-A}$$

The rotor position in relation to stator phases thus can be found. The phase angles of readings A and C will be $(\theta+120)$ degrees and $(\theta-120)$ degrees, in this order or

vice versa, according to the values associated with A, B, and C.

For any given value of tan θ there are two angles, in opposite quadrants and differing by 180 degrees, that satisfy. Care would be necessary, therefore, in choosing the proper quadrant for θ. Determination of the values of angles, however, is quite unnecessary in the calculations of subtransient or negative-sequence reactances, the angles merely indicating the rotor position, which is not important when this method of test is used.

Reactances, from terminal to neutral, in ohms, will be

$$X_d'' = \frac{K-M}{2}$$

$$X_q'' = \frac{K+M}{2}$$

$$X_2 = \frac{K}{2}$$

$$\frac{X_q''}{X_d''} = \frac{K+M}{K-M}$$

When per-unit values of subtransient and negative-sequence reactances are desired, their respective values in ohms, as calculated here, will be multiplied by rated stator amperes per phase and then divided by rated stator volts from terminal to neutral.

The series of tests may be repeated, with the rotor turned to any new position by its turbine. Readings again may be taken in any order and would give the same values of K and M, thus serving as a check on the first series. In fact, the series of tests may be repeated as often as desired, with different positions of the rotor, the limitation, however, being the heating of the damper windings which will necessitate spacing of readings in time so as to prevent overheating.

The method of test greatly simplifies the measurement of subtransient reactances for it is not necessary to uncouple the turbine from the generator nor to move the rotor through small angles to special positions by improvised means at the generating stations. The position of the rotor poles in relation to stator phases is not important in this test. Rotor currents do not enter the calculation and therefore need not be measured unless desired as further information.

In these calculations, vector phase relations disappear and only scalar quantities are used. As readings may be taken in any sequence and introduced into the formulas in any order, the tracing and recording of phases during the tests are not required. Check tests are made very easily. From all viewpoints, this appears to be a thoroughly practical method of test which already has given satisfactory results and been favorably recommended by manufacturers of large synchronous machines.

MAXIMUM INDUCED ROTOR CURRENT

In connection with subtransient reactance measurements, it may sometimes be desirable to know the maximum possible current that can be induced in the rotor windings with rated stator current flowing. If, in the foregoing tests, the induced rotor currents are read and compared with stator currents for the three rotor positions, A, B, and C, the maximum possible value of induced rotor current for rated stator current can be calculated easily.

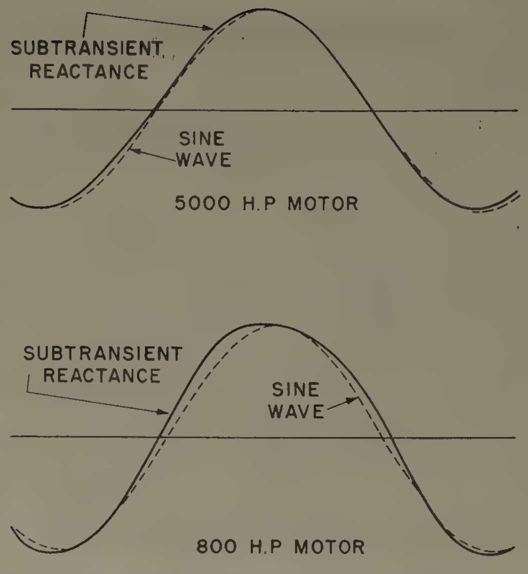

Figure 2. Variations from pure sine wave of actual waveforms of subtransient reactance of synchronous machines, determined by test. Damper windings not connected between poles

Whereas the plotted results of subtransient reactances for a series of rotor positions across one pole span give a displaced sine wave, the plotted values of induced rotor current, corresponding to rated stator current or any other one chosen value, will give a fully rectified sine wave having 1/2 cycle per pole span, the maximum value occurring with that rotor position which gives direct-axis subtransient reactance, and the zero value corresponding to the position which gives quadrature-axis subtransient reactance, Figure 1B.

The procedure is to let the three induced rotor currents, rms values, each corrected to correspond to rated stator current, be X, Y, and Z, with X being the highest value. The maximum possible rms value of induced rotor current P then may be calculated by the formula

$$P = \sqrt{X^2 + \frac{(Y-Z)^2}{3}}$$

There are, however, two special cases:

1. If there are two equal high values, that is, if either Y or Z be equal to X, the third reading will be zero. In this case

$$P = \frac{2X}{\sqrt{3}}$$

2. If Y equals Z, the second term in the formula then becomes zero, and $P = X$.

As with measurements of subtransient reactances, the rotor in any other position should give the same value of P, the maximum possible induced current in the short-circuited rotor.

THE SINE WAVE OF SUBTRANSIENT REACTANCE

It was explained in the theory of this simplified method of test that plotted values of subtransient reactance, meas-

ured with various rotor positions across a pole span, gave a displaced sine wave, Figure 1*A*. With fully connected damper windings, the amplitude M of this wave is very low so it is difficult to determine its form accurately by actual tests. With nonconnected damper windings, however, the wave is of much higher amplitude and tests on small machines have verified the sine form absolutely.

On some larger synchronous motors, with nonconnected damper windings, slight departure from the sine form has been observed, Figure 2. This has been noticed in calculations by small variations in values of M for different rotor positions. The value of K, the offset of the wave, does not appear to vary appreciably.

Further studies are being made with a view to determining the cause of these minor variations. At the present time it is thought that they may be associated with certain stator slot positions in relation to damper bars.

THE POSSIBLE RANGE OF STATOR CURRENT

IT HAS BEEN customary to use 40 to 50 per cent of rated stator current in measuring subtransient reactances, with stationary rotor, the limitation in current being the possible overheating of the damper windings when too high a current is used. Some tests, however, have been made by the authors with lower currents, over a range from very low values up to half rated values. This matter is being studied, by tests, to simplify further the making of measurement by using the lowest reliable values of stator currents.

STUDYING DAMPER WINDING DESIGN

DURING the development and application of this new method of measuring subtransient reactances of synchronous machines, the authors had the opportunity to test two small synchronous motors under the three possible arrangements as to damper windings: 1. without damper windings installed, 2. with dampers installed but not connected between poles, and 3. with fully interconnected damper windings. The results of this investigation showed clearly the effect of introducing damper windings into a machine which had none before and also the advantage gained by interconnecting the cages between poles. As tests by this new method are made easily, an investigation of this nature is now readily possible in the factory and will supply information of inestimable value to the design engineer enabling him to study the advantages of different sizes, spacing, and materials of damper bars, and to determine the extent of the benefit to be gained by inserting dampers and by their interconnection between poles. This method of test therefore facilitates the obtaining of new information to aid the engineer in designing synchronous motors and generators.

CONCLUSIONS

THE SIMPLIFIED methods of measuring subtransient reactances, negative-sequence reactances, and maximum possible induced currents in short-circuited rotor windings of synchronous machines are submitted here for the first time.

These new test methods are extremely simple and remarkably flexible, especially of advantage for large generators. It is not necessary to uncouple the turbine or to move the rotor through small angles to special positions, both of which operations are difficult to perform in the field. The actual position of the rotor in relation to stator phases is quite unimportant. Readings may be taken in any sequence and introduced into the formulas in any order. Vector phase relations disappear and only scalar quantities are used. Check tests can be made easily by turning the rotor by its turbine and letting it stop in any new positions. Actual applications of the method have produced very satisfactory results on salient-pole generators over a wide range of rating. The maximum possible value of induced rotor current, with rated stator current, may be obtained readily from rotor current measurements taken at the same time as those for determining subtransient reactances.

Having experienced the difficulties encountered in field testing where it was necessary laboriously to uncouple the turbines and to shift the rotors of large generators through small angles, the authors feel that these new test methods, avoiding these problems, will be fully appreciated by others who have had similar experiences. The chief caution to be heeded is that stator currents be kept below rated values to avoid overheating in the rotor. Tests will be brief but currents must be held steady to insure consistent readings.

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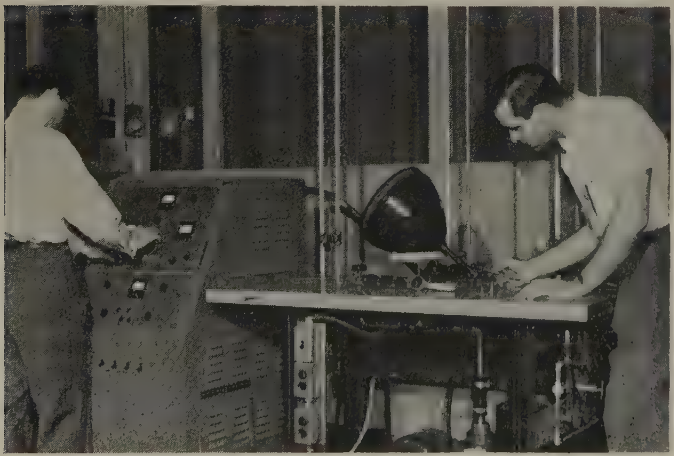
Cathode-Ray Tube Leak Detector



Detection and location of minute openings in cathode-ray tubes is being done by use of a General Electric type-M leak detector at the Lansdale (Pa.) Tube Company. The tube being tested is connected through the detector to a vacuum pump. Helium then is shot under pressure against the surface of the tube being tested. If there are any openings in the tube, the helium will be drawn through them and into the detector. The detector, which is sensitive to helium, will indicate instantly the presence of the element and the tube will be rejected

Forced-Air Cooling for Station Cables

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IN MODERNIZING OLDER existing stations in connection with plant capacity addition programs, difficulties often are encountered in installing adequate generator outlet capacity for modern generators several times larger in rating than the older units being replaced. In some cases the use of forced-air cooling may be justified as a means of increasing cable capacity well beyond the self-cooled rating of the installation.

Adequate air supply is drawn from outdoors by a blower, passed through filters, and routed by suitable air-duct connections to the cable-duct entrances, as shown in Figure 1, finally flowing out at a convenient exit point in a terminal chamber at a design temperature limited to keep conductor temperature below prescribed limits.

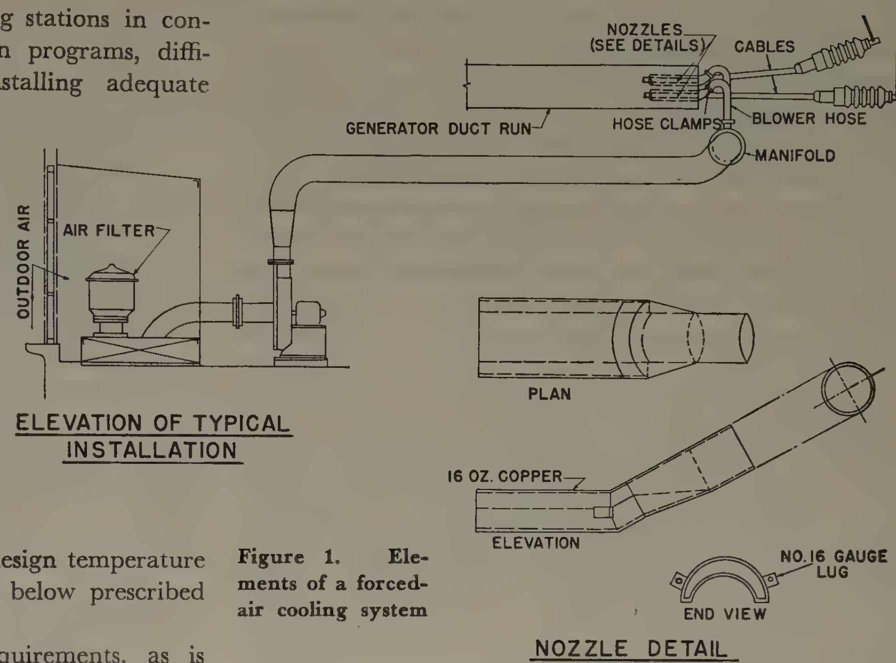

Figure 1. Elements of a forced-air cooling system

Determination of the air-supply requirements, as is usually the case in ventilating and air-conditioning problems, cannot be precise. Designs based on general thermal principles and applied liberally will produce satisfactory results. It is recommended that air supply be based on absorbing total cable losses and that the forced-air system be broken up into duct runs of not more than 100 or 200 feet, depending on duct friction.

For the average case with duct bank external ambient of 40–50 degrees centigrade, it has been found satisfactory to determine air requirements by means of the equation

$$\text{Cubic feet per minute (CFM)} = 1.93WL/(T_e - T_i) \quad (1)$$

where W is the watts loss per foot of cable, L is the length of run in feet, T_e is the exit air temperature, and T_i is the duct inlet air temperature.

Exit air temperature must be kept below the allowable sheath temperature by an amount depending on the effective resistance between sheath and moving air. A formula for determining this effective resistance has been developed

$$R_{sa} = 6.0(D_e/CFM)^{0.8} \text{ degrees centigrade per watt per foot} \quad (2)$$

where D_e is the equivalent diameter based on the cable (heat transfer) perimeter.

Inlet air temperature will be somewhat above source air temperature as a result of compression rise added by the blower. Blower-temperature rise characteristics, as a function of differential pressure required, should be determined by test. For practical purposes, differential pressure may be taken as approximately proportional to the square of the air flow.

The pressure drop in the inlet system, blower, and exhaust piping may be determined by conventional methods. Pressure drops in the cable-duct system are best determined by actual tests on the system involved at a suitable range of air flow. On the basis of a number of such tests, an empirical equation for the mean curve resulting has been expressed in the form

$$\Delta p = 13.3 \times 10^{-9} LV^2/(D_2 - D_1)^{0.88} \text{ inches of water} \quad (3)$$

where L is the length of run in feet, V is air velocity in feet per minute, and D_2 and D_1 are the duct diameter and cable diameter, respectively, in inches.

Equation 1 neglects lateral heat transfer through the duct bank structure. For average duct bank ambients of 40–50 degrees centigrade, experience indicates the use of equation 1 to be satisfactory, especially if the design is applied liberally. In boiler rooms, external ambients may in some cases approach 60–65 degrees centigrade in the summer and there may be effective heat transfer inward through the duct structure for appreciable portions of the run. For such cases air-supply requirements may be calculated more accurately by the equation

$$T_e - T_i = (T_a - T_i + W.R_b)(1 - e^{-1.93L/(CFM\,R_b)}) \text{ degrees centigrade} \quad (4)$$

where T_a is the duct bank external ambient air temperature and R_b is the duct bank thermal resistance per duct per foot of run.

Digest of paper **51-327**, "Forced-Air Cooling for Station Cables," recommended by the AIEE Committee on Insulated Conductors and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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A Heavy-Duty Slip Regulator for Steel Mill Service

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SLIP REGULATORS have been applied successfully to blooming mills as early as 1913 where the heavy impact load peaks of the mill motors would result in excessive power surges. An installation of this type often consists of a wound-rotor induction motor driving a flywheel motor-generator set. The secondary of the motor is connected to a slip regulator which automatically increases its resistance in case of heavy load peaks, thereby permitting the set to slow down and give up part of its stored kinetic energy. In this manner it is possible to supply high momentary load peaks to the mill motors with a practically constant power demand from the a-c supply.

A new compact design of slip regulator, as illustrated in Figure 1, is now in production. This design features three separate cell assemblies insulated from each other, forced electrolyte circulation for higher thermal efficiency, a modern heat exchanger for maximum cooling efficiency, and a simple operating mechanism and regulating system.

The submerged pump forces the electrolyte through the heat exchanger into the header at the top of the regulator and from there down the stand pipe to a pressure chamber below the stationary from which the electrolyte can flow upwards in the cell toward the moving electrode while carrying the motor current. Subsequently, it passes through corresponding openings in the moving electrode and then rises to the top of the cell where it overflows and returns to the sump tank. This method of circulation insures a positive removal of the heat between the electrodes and thereby will permit a greater current density and a higher regulator load as compared to a system depending on natural convection. The insulating cells for the three phases are made of heavy asbestos cement, vacuum-dried and impregnated with tung oil under heavy pressure. This insures a high-grade insulation.

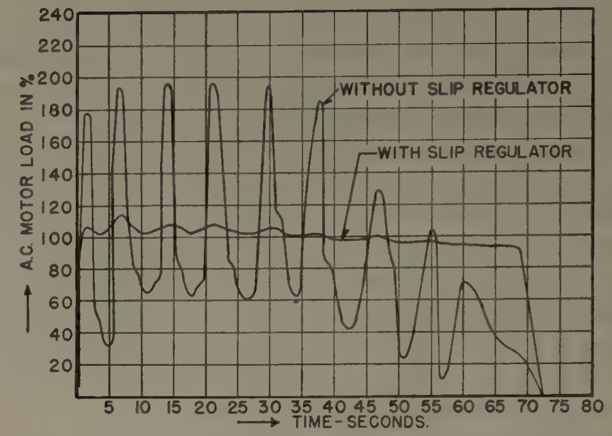

Figure 2. Performance of a 6,000-horsepower blooming mill showing power surges of a-c motor during a complete rolling cycle with and without slip regulator

The operating mechanism consists of a pilot motor driving the counterbalanced moving electrodes through a self-contained gear unit. The pilot motor is energized from a Rototrol, the output of which is proportional to the difference between a fixed reference field and a regulating field measuring motor current.

At normal load, the reference and regulating fields are balanced and the Rototrol output therefore is zero. When the motor load exceeds this value, the regulating field excitation predominates and the Rototrol will supply power to the pilot motor so as to increase the electrode separation, thereby reducing the a-c motor load. The opposite takes place after the power peak has disappeared. The reference field ampere turns now are higher and produce a Rototrol voltage that will bring the electrodes together until the limit switch stops the travel when the electrodes have reached minimum spacing.

Sodium carbonate dissolved in clean water has been found to be the electrolyte best suited for slip regulators and is used normally in concentrations varying between 0.5 and 5 per cent. The possibility of varying its density makes the application of slip regulators very flexible.

A typical operating cycle of a 6,000-horsepower blooming mill is illustrated in Figure 2. It shows the performance of the drive with the slip regulator adjusted to have zero Rototrol output at 100-per cent load. Note that without the regulator the power peaks are as high as 3,150 kw, while with the slip regulator in operation the surges are reduced to a negligible value.

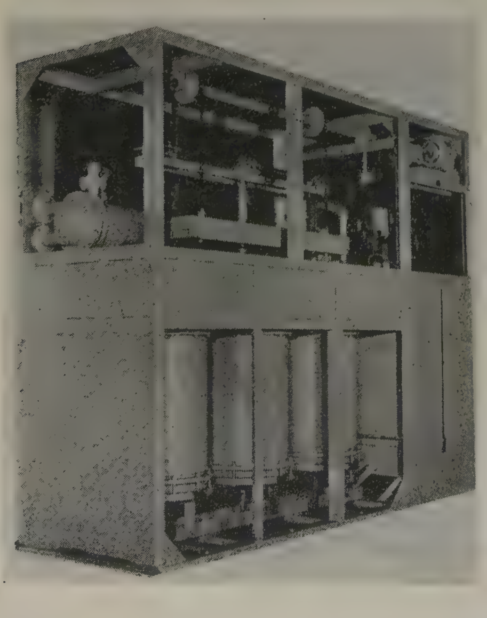

Figure 1. New type heavy-duty slip regulator

Digest of paper 51-322, "A Heavy-Duty Slip Regulator for Steel Mill Service," recommended by the AIEE Committee on Mining and Metal Industry and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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A-C Motors for Driving Oil Well Pumping Units

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MANY TYPES OF a-c motors are used to drive oil well pumping units. The diversity of choice of motors suggests that the various types are equally desirable, but this is not the case. Experience and a more fundamental approach to the evaluation of motors for oil well pumping substantiate the conclusion that 5- to 8-per cent slip motors in a dripproof or protected frame should be purchased for installations where 3-phase power is available. Two-value capacitor-type motors in a dripproof or protected frame are preferred where single-phase power must be used.

Factors to be considered in selecting the motor are the starting requirement, the performance of the motor with the various characteristics when applied to the load encountered on pumping units, and initial cost.

Measurements of the torque required to start pumping units are not available, but experience has shown that motor-starting torque must be greater than that required for ordinary service. To insure positive starting and minimum cost for distribution lines, motors having the highest starting torque and the lowest starting current should be used. Considering initial cost, 5- to 8-per cent slip motors are first choice from the standpoint of starting performance.

The running load encountered on oil well pumping units is characterized by high peaks and wide and rapid load variation. The exact load versus time relationship is influenced by many factors and is different for each installation. Therefore, general conclusions cannot be reached from a test of one installation.

Electrical measurements taken on tests of 17 different electric motor-driven units, 6 of which were driven by normal slip motors and 11 of which were driven by 5- to 8-per cent slip motors, gave by direct reading or by calculation peak-power input to the motor, average motor power input, rms current, and power factor. Conclusions reached from these tests are as follows:

1. The use of 5- to 8-per cent slip motors instead of normal slip motors will result in 25-per cent lower peak-power input. Therefore, line voltage fluctuation and the load variation imposed on generating plants installed in the field to serve oil well pumping units will be less with 5- to 8-per cent slip motors than with motors which have normal slip.

2. Motors driving pumping units cannot average an output equal to name-plate rating without being overloaded thermally. To prevent thermal overload, normal slip motors should be sized on the basis of being capable of averaging an output of 56 per cent of name-plate rating and 5- to 8-per cent slip motors should be sized on the basis of averaging an output of 76 per cent of name-plate rating. This procedure is considered adequate for 85 to 90 per cent of all pumping unit installations.

3. Oil producers obtain 15 to 30 per cent more horsepower capacity per dollar invested by purchasing 5- to 8-per cent slip motors instead of normal slip motors.

4. At a given per cent load, 5- to 8-per cent slip motors operate with 20 points higher power factor than normal slip motors.

The relative efficiency of normal and 5- to 8-per cent slip motors in oil well pumping service must be determined by tests on many wells where the kilowatt-hours used per barrel of liquid lifted is determined for both normal and high-slip motors when pumping a given well at the same stroke and strokes per minute. Three such tests showed normal slip and 5- to 8-per cent slip motors to be equally efficient, but additional tests are required to reach a firm conclusion.

Ordinary thermal overload relays will not protect 5- to 8-per cent slip motors from stalled single phase. This has not proved to be a disadvantage of 5- to 8-per cent slip motors because devices usually incorporated in oil well motor controls can be connected in a manner such as to prevent motors from being subjected to stalled single phase.

Motors installed on pumping units must operate in the open. Types of frames available for outdoor service are totally enclosed fan-cooled, splashproof, protected frame, and dripproof. Experience has shown that the 40-degree centigrade dripproof and protected-frame motors are satisfactory for more than 99 per cent of all pumping unit installations. Motors built in these frames are preferred because of their lower initial cost and greater thermal capacity compared to motors built in other types of frames. Specifically, dripproof and protected-frame motors have 20 per cent more horsepower capacity per dollar initial cost than splashproof motors and have 61 per cent more horsepower capacity per dollar initial cost than totally enclosed fan-cooled motors.

Motors rated 440 volts have been used most widely for oil well pumping service. However, consideration of Y-connecting 440-volt motors to operate at 760 volts is recommended where the distance between wells will be greater than 660 feet and where individual well loads will be greater than 25 horsepower. The Humble Oil and Refining Company has made a number of such installations and performance is reported to be satisfactory.[1]

Digest of paper 51-384, "Selection of A-C Motors for Driving Oil Well Pumping Units," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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The Effect of Unit Size on Steam-Electric Generating Station Design

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As the size of power systems and the capacity of interconnections continue to increase, the economic factors which affect the design of larger generating equipment and stations become more important. Such advantages as lower investment cost per kilowatt, higher efficiency, and lower operating costs are considered in this article.

IN THE EARLY YEARS of electric power systems, the use of the larger generating units was confined to a very few systems, generally those serving concentrated metropolitan loads. The development of the integrated power system with a backbone of high-voltage transmission circuits led to the concentration of power generation at a few favorable locations. The natural increase in system loads which has resulted, on an average, in the doubling of system peaks every 11 years led to the use of increasingly larger generating units. High-capacity interconnection between adjacent systems gave additional impetus to this trend. Interconnections between systems were installed to take advantage of the diversity of times of the peak loads on different systems and so reduce the total installed generating capacity. By proper design of the transmission systems, it then became feasible to use increasingly larger generating units more generally, as the combined reserve capacity of all the interconnected systems was available in the event of loss of a large unit of generation.

The selection of the amount of generating capacity that can be added economically to a power system depends upon such factors as the location on the system of the new capacity, the transmission facilities available, the rate of load growth on the system, the location of this load, and a consideration of reserve requirements.

Several factors have had an influence on the size of individual generating units that have been installed, among which the following are important:

1. Investment cost per kilowatt of generating capacity.
2. Net plant heat rate.
3. Operating cost per kilowatt.
4. Maintenance cost.

To clarify the discussion that follows, certain terms that will be used are defined.

Kilowatt Rating of a turbine-generator set, as used this in discussion, is the maximum guaranteed kilowatt output of the unit. This rating is used rather than the more conventional name-plate rating as it determines the ratings of most other equipment in the station. As an example, an 80,000-kw machine with 25 per cent overload capacity is considered to be a 100,000-kw unit. Similarly, a preferred standard 60,000-kw unit with 10 per cent overload capacity is considered to be a 66,000-kw unit.

Turbine Heat Rate. Gross turbine heat rate is used in making comparisons of different turbine-generator sets for the same initial pressure and is defined as

$$\text{turbine heat rate} = \frac{\text{net heat input to turbine}}{\text{generator output}}$$

$$= \frac{(\text{throttle enthalpy} - \text{final feedwater enthalpy}) \times \text{steam flow}}{\text{generator output}}$$

This value, modified by boiler feed pump power as a function of boiler pressure, can be used as a basis for comparing the performance of units of various sizes if it is assumed that boiler efficiency and the percentage of the output required for the other auxiliaries are constant regardless of unit size.

INVESTMENT COST

IT IS DIFFICULT to compare the costs of generating stations having different size of generating units because local factors distort the observable trend of total station cost. However, consideration of the cost of some of the major items of station equipment, representing at least two-thirds of total station cost, indicates some general trends in station cost for different size units.

Figure 1 shows the cost, in dollars per kilowatt of turbine-generator capability, of 3,600-rpm turbine-generator sets in the size range from 40,000 to 160,000 kw. (These values are approximate and based on published prices as of March 1951.) The solid curve is for steam conditions of 1,250 pounds per square inch gauge and 950 degrees Fahrenheit, and shows that substantial savings can be realized in the larger units. The dotted curve above is for steam conditions of 1,800 pounds per square inch gauge and 1,050 degrees Fahrenheit and shows a slightly greater downward slope. The upper dotted curve is for steam conditions of 1,800 pounds per square inch gauge and 1,050 degrees Fahrenehit with reheat to 1,000 degrees Fahrenheit and shows a still greater downward slope. The greater downward slope of the cost curves for higher steam

Full text of paper 51-155, "The Effect of Unit Size on Steam-Electric Generating Station Design," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE North Eastern District Meeting, Syracuse, N. Y., May 2–4, 1951. Not scheduled for publication in AIEE *Transactions*.

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The authors wish to acknowledge the helpful suggestions and constructive criticism of E. E. Harris, W. D. Marsh, E. E. Parker, H. G. Schiff, Jr., and H. D. Taylor.

conditions and for reheat machines can be explained by the fact that almost the same amount of material is subjected to the higher temperatures and pressures regardless of the size of the unit. For this reason, so far as turbine-generator cost is concerned, it is easier to justify using high temperature and reheat in larger units than in small units.

The turbine-generator costs, based on 3,600-rpm units, were used to illustrate the trend, because this type of unit is the only one available over a wide range of sizes. In the region above 100,000 kw, both 1,800-rpm and cross-compound units, comprising separate high- and low-pressure units, are available in still larger capacities. While these units are somewhat more costly, they also show a continued downward trend in cost with the cross-compound units being more pronounced.

On the assumption that only one boiler per turbine would be used even on the largest units, the curves of cost against size for boilers would show similar characteristics to those for turbine-generator sets.[1]

Figure 2 shows similar cost comparisons for main step-up transformers. These data are based on a high voltage of 138 kv. The kilovolt-ampere rating of the transformer was made equal to the 15-pound hydrogen rating of an 0.85-power factor generator that might be associated with each of the maximum capability turbines.

As the sizes of boilers and turbine-generator sets increase, the building space required per kilowatt of generating capacity decreases. With present high building costs this may result in a worth-while saving for the larger units.

TURBINE HEAT RATES

Figure 3 shows turbine heat rates against size for 3,600-rpm turbines under steam conditions of 1,250 pounds per square inch gauge, 950 degrees Fahrenheit, $1^1/_2$-inches mercury back pressure, 410 degrees Fahrenheit feedwater temperature and with no boiler feed pump power included. The left curve includes tandem-compound double-flow units with 14-, 16-, and 20-inch buckets in the last stage. The middle curve is for a double-flow unit with 23-inch last stage buckets and the right curve for a triple-flow unit with 23-inch last stage buckets.

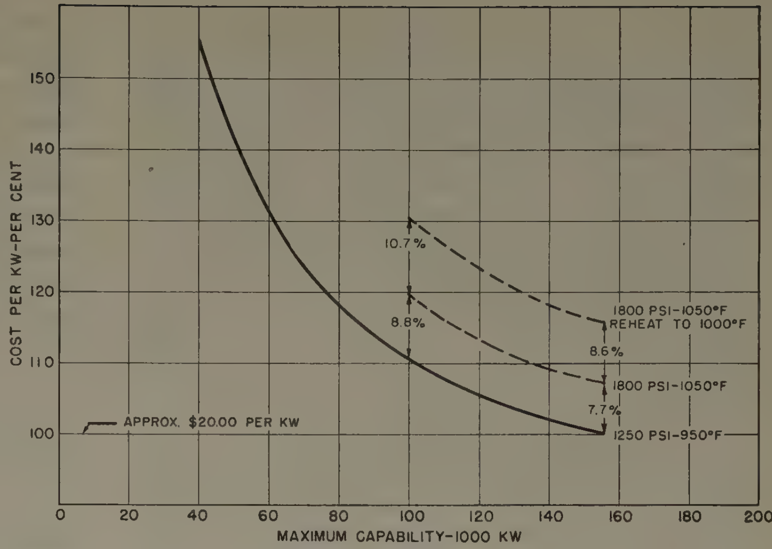

Figure 1. Relative costs of various sizes of 3,600-rpm turbine-generator sets

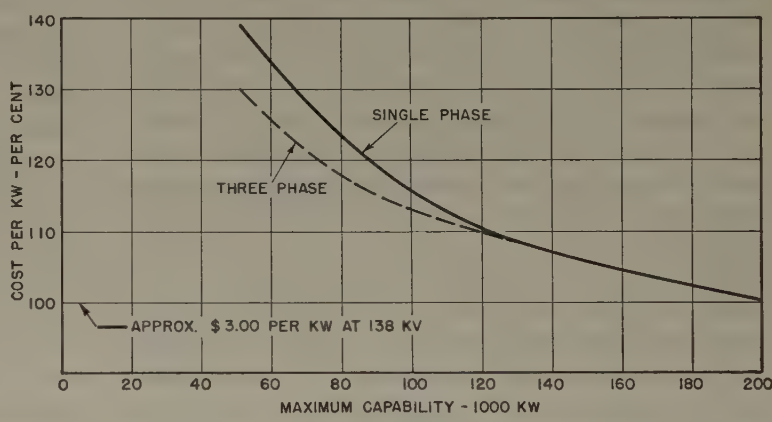

Figure 2. Relative costs of various sizes of type OA/FA power transformers

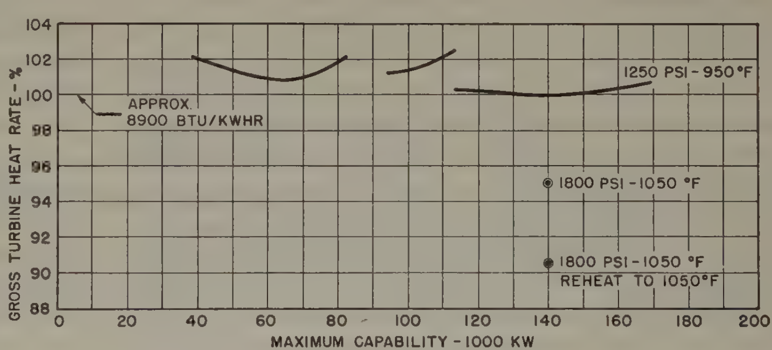

Figure 3. Relative heat rates for various sizes of 3,600-rpm turbine-generator sets

It should be recognized that 3,600-rpm units are not used universally over this range of sizes. In the region above 100,000 kw many users, with very sound reasoning, purchase straight 1,800-rpm units or cross-compound units. The 1,800-rpm units have larger exhaust areas and therefore improved economy where cooling water temperatures give good vacuum. These units are more expensive than 3,600-rpm units at the temperatures shown and still more expensive at higher temperatures because of the bulk of high temperature material involved. Present-day design considerations have limited the selection of 1,800-rpm units to steam conditions of 1,450 pounds per square inch gauge and 1,000 degrees Fahrenheit and below. The most efficient combination in the larger sizes, which is still more expensive, is the cross-compound unit making use of an efficient 3,600-rpm high-pressure unit and the larger

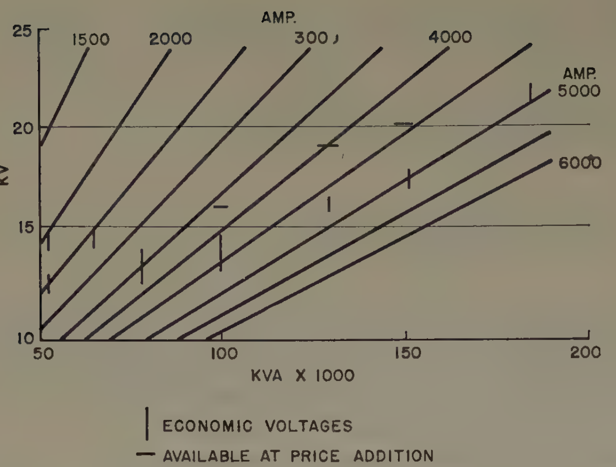

Figure 4. Economical voltages for large 3,600-rpm generators

exhaust area possible in an 1,800-rpm low-pressure unit.

These variations have not been included in the plotted data to avoid confusion. The choice of turbine-generator set in a specific case can be made only after evaluating efficiency, fuel cost, cooling water temperature, and expected load factor. With fixed steam conditions and 3,600-rpm units, Figure 4 shows that for the whole range in size between 40,000 and 160,000 kw there is a change of not more than 2 per cent in heat rate. This supports the conclusion that for fixed steam conditions and the same design speed, increasing the size of a unit has little effect on efficiency.

By changing the initial steam conditions from 1,250 pounds per square inch gauge, 950 degrees Fahrenheit, to 1,800 pounds per square inch gauge, 1,050 degrees Fahrenheit, the heat rate will be improved by approximately 5 per cent throughout the size range. In practice these higher temperatures and pressures are not used in the smaller sizes.

By reheating to the initial temperature a gain of 4 to 5 per cent in heat rate can be made at either of these steam conditions.[2]

These two conditions are shown in Figure 3 for a maximum capability unit of 140,000 kw and these two points may be used to establish two other sets of curves similar to the ones shown in full.

The number of men required to operate a unit in a station is practically independent of the size of the unit. Thus as unit size increases there is a direct and proportional reduction in the cost of this item per kilowatt-hour. The magnitude of this saving can be as significant in the total cost of a kilowatt-hour at the bus as an appreciable reduction in net plant heat rate. This is particularly significant when it is realized that heat rates are not being lowered rapidly these days and when they are some premium in investment is required.

MAINTENANCE

As a result of experience to date, larger units can be expected to be as reliable as the smaller units. Similarly, high temperature, high pressure, and even reheat units are expected to have practically the same reliability as the older machines.

Outage time for either repair or inspection of the larger units may be somewhat greater than for the smaller sizes but probably not longer than that required by the boilers with which they are associated. Data are not available to apply numbers to this outage time. The practice of some companies in having a roving maintenance force should help in reducing this time as a few more men can be added where required and where they can be used to advantage. In any case, this is a very small item in the total cost of generating a kilowatt-hour.

EFFECT OF SIZE ON EQUIPMENT DESIGN

Turbines. In general, the maximum output of any turbine is determined by the maximum steam flow which will pass through the last row or rows of buckets without excessive leaving losses which would impair efficiency. Mechanical considerations determine the maximum length of bucket that can be used on the last stage of a turbine and thus set a limit on the maximum possible annulus area. The volume of steam that must pass through the last stage depends to a large extent on the vacuum that can be maintained and so the maximum efficient output of a turbine will vary depending on the available cooling water temperature. To meet these conditions as turbine size has increased, various types of turbines have been developed.

1. Single casing units have a single steam path from throttle to exhaust. At 1,800 rpm the maximum capability is about 110,000 kw and at 3,600 rpm about 35,000 kw.
2. Tandem-compound double-flow units consist of a single high-pressure turbine and two low-pressure turbines on the same shaft. This doubles the available exhaust area and allows approximately twice as much steam flow. Approximate maximum capabilities to date are 175,000 kw at 1,800 rpm and 110,000 kw at 3,600 rpm.
3. Tandem-compound triple-flow units consist of a single high-pressure turbine and three low-pressure turbines on the same shaft. These units have been built only at 3,600 rpm and the approximate maximum capability to date is 160,000 kw.
4. Cross-compound units consist of a high-pressure noncondensing turbine driving its own generator and a low-pressure condensing turbine using exhaust steam from the high-pressure unit and driving its own generator. Use of these units is usually confined to maximum capabilities of 125,000 kw and up. Most cross-compound sets have had 3,600-rpm high-pressure units and 1,800-rpm low-pressure tandem-compound double-flow units.
5. Reheat turbines have been of two general types used in the resuperheating cycle in which steam is returned to the boiler at 300 to 400 pounds per square inch gauge and resuperheated back to almost the initial temperature: cross-compound units as already described and limited to the larger outputs; and tandem-compound 3,600-rpm units, either double- or triple-flow and ranging in size from 50,000 to 160,000 kw. The turbine construction used by the company with which the authors are associated permits having all high-temperature parts adjacent, thereby reducing stresses and resulting in a very compact design.

This briefly outlines current practice in turbine design in regard to the types of turbines and the maximum size of each type that has been built. In a particular case, involving a specific location and a predetermined block of generation, detailed studies must be made in which turbine heat rate, fuel cost, and associated plant costs are evaluated to determine the most suitable type of turbine. The selection of the type of turbine will have some influence on the generator voltages and the type and arrangement of the main power connections and step-up transformers, but will have little effect on the electrical design of the remainder of the station. The output capability of the steam-generating apparatus and the manner in which the auxiliaries are subdivided will have a very direct influence on the type of auxiliary power system and size of motors.

It appears that until the installed cost of station components not only has leveled off but has increased sufficiently to offset the saving in operating cost or until the use of larger units results in an appreciable increase in reserve capacity, there will be a continued demand for larger single blocks of power. Single 1,800-rpm turbine-generator sets can be built in larger sizes than are now in use, but present-day design limitations prevent their use for the highest pressures and temperatures. The size of 3,600-rpm turbine-generator sets has increased at an astounding rate to the point where designs are now contemplated well beyond actual operating experience. The immediate demand for larger blocks of power can be met conservatively by using cross-compound units where the components are well within design experience. At the same time, maximum economy results from the high-speed high-pressure turbine and from the low-speed low-pressure turbine.

Generators. From the standpoint of the main power circuits in the station, 1,800-rpm turbine generators offer the greatest flexibility. They may be designed as 1-, 2-, or 4-circuit machines with the larger ones being 4-circuit. With present bushings and by using two sets of bushings on a large 4-circuit generator it is practical to consider a total output at 1/2 pound hydrogen pressure of 10,000 amperes with voltages in the 15-kv class. In applications where power is distributed at generator voltage there has been a limited demand for double-winding generators where each half of the generator winding was connected to a different bus section to reduce switchgear short-circuit requirements. This type of service demanded a special generator design to accommodate unbalanced loading on the two armature windings. In the unit-type system where two sets of generator bushings are used because of current limitations, but where no unbalance between the two windings is possible, it is not necessary to design such a generator for unbalanced operation.

As generator sizes increase to keep pace with increases in 3,600-rpm turbine sizes, it becomes more and more difficult to design a satisfactory machine at the previously accepted standard voltage of 13.8 kv. For many years this was a standard generator voltage largely due to its having become a standard system voltage. Very few of the new larger machines will supply power to a system at generator voltage so there is no longer any necessity for keeping the generator voltage at 13.8 kv.

Figure 4 is a plot of generator kilovolt-amperes against generator voltage of large 3,600-rpm machines which have been designed for the most economical voltage. Lines of constant armature current are drawn in and it should be noted that most of the points cluster around the 5,000-ampere line. This is approximately the maximum current that can be carried by the conductors used in a 2-circuit 3,600-rpm machine when operating at 1/2 pound hydrogen pressure.

If maximum use is to be made of the material used in the generator, the designer has little freedom in varying design parameters. As size increases, variation of the number of stator slots permits changes in generator voltage, but this can be done only within a narrow range for an economical design. Voltage can be changed within a still narrower range by changing coil pitch but this is only a minor variation.

For large generators, the optimum voltage is determined by the point at which armature current becomes excessive. Consequently, choice of voltage is limited to the optimum or higher.

Since almost all very large generators are connected directly to step-up transformers, there is no reason why any new generator voltage should be considered standard. The designer should be given free choice so that selection of the voltage will result in the most economical and best generator design.

It is difficult to design satisfactory 3,600-rpm double-winding generators for unbalanced operation. In cases where it is necessary to supply power to two busses at generator voltage, and where it is desired to avoid the complexity of double-winding design, a single-winding generator connected through a duplex reactor can be used. This provides low through reactance between the generator and the busses but high reactance between the two busses, thus keeping the short-circuit values on the busses to a minimum.

As 3,600-rpm generator size increases above about 100,000 kva, the current that must be carried by the field windings, collector rings, field circuit breakers, and the exciter commutator becomes excessive if 250 volts is used as an excitation voltage. Therefore, generators above this size should have 375-volt fields to reduce the cross section of the field winding and the duty on other equipment.

Main Power Connections. The high currents, up to 5,000 to 6,000 amperes, associated with large generators require several cables in parallel per phase for the connections from the generator terminals to the step-up transformer. Terminations for this type of cable run are expensive and for these important connections cable presents a potential source of trouble.

Isolated-phase bus run of current carrying capacity up to 7,000 amperes has been developed which offers increased reliability and low maintenance costs. Tap-offs for the auxiliary power transformers, potential transformers, surge protective capacitors, and lightning arresters can be

provided readily with complete phase isolation being maintained throughout these connections.

Isolated-phase bus run is available in two designs: one to meet a 60-cycle 50-kv test and an impulse test of 110 kv (50/110 kv) and the other to meet a test of 60/150 kv and so can be used with any generator being designed at present. Although more expensive than cable, isolated-phase bus run is being accepted increasingly, particularly for short runs. In most stations, the length of the run can be kept to a minimum by locating the main transformer immediately outside the station wall.

Transformers. Practical sizes of 3-phase transformers now are limited by shipping requirements and generators now are being designed and cross-compound installations are being planned that exceed the kilovolt-ampere rating of the largest 3-phase transformers that have been built. In such cases, two or more 3-phase transformers operating in parallel and connected to the high-voltage system through a single circuit breaker or alternatively, three single-phase transformers, can be used. Consideration of spare transformer capacity will be an important factor in determining which solution is followed.

To reduce the physical size of transformers for a given rating, it has become common practice to use forced cooling. As more intensive types of cooling are used not only the size but the first cost of transformers decreases. Thus, progressively the types oil-immersed forced-air-cooled (fans with radiators), oil-immersed forced-air-cooled forced-air-cooled (high-velocity fans with radiators), forced-oil air-cooled, and forced-oil water-cooled with external heat exchanger are smaller and less costly.

EFFECT OF SIZE ON GENERAL STATION DESIGN

Along with the development of larger generating units has come the general acceptance of the unit system of station design. There are several reasons for this development among which the following are important:

1. The reliability of modern boilers, turbine-generators, and transformers has made it possible to eliminate all steam connections and electric connections at generator voltage between units in a station without any appreciable sacrifice in reliability or availability. This simplification, regardless of the size of generating units, results in a large saving in cost which becomes more important as unit size increases.

2. The output of very large generators may exceed the current rating of available circuit breakers at generator voltage, making it impractical or at least very expensive to bus generators at low voltage. If several generators are bussed at generator voltage, the interrupting rating of available switchgear will be exceeded.

3. The output of many generators is so large that it is not practical to attempt to distribute the power at generator voltage and so the need for generator busses no longer exists.

4. The trend to higher temperatures and pressures has made provision of steam headers very expensive. The use of the reheat cycle has made this a more important consideration as the cost of providing primary steam headers, return headers, reheated steam headers, and feed-water headers and the operating complications involved, such as the division of return steam to the reheaters, would be prohibitive.

The use of the unit system has been extended to the auxiliary power system with a separate system being provided for each generating unit. In general, the only tie between the auxiliary power systems of different units in a station is the use of a common starting transformer from the system. Figure 5 shows a typical 1-line diagram of such a station. Figure 6 shows some typical solutions for connecting various generator arrangements to the system.

Large boilers almost always have their essential services divided between two pieces of equipment, that is, there are two or three induced draft fans, two forced draft fans, two or more boiler feed pumps, and probably four coal pulverizers, and so forth. This division of essential auxiliaries lends itself to the use of either two busses or at least a single bus that can be sectionalized so that in the event of trouble on one bus, the unit can continue to be operated at half load or more.

In most stations, the larger motors are supplied at 2,400 volts and the smaller ones at 480 volts. By using two busses, each supplied by its own transformer, the 2,400-volt system can be used for single generating units up to 125,000 kw or more. As generating unit size increases beyond this point, the amount of auxiliary power required becomes so large that the interrupting rating of available 2,400-volt switchgear will be exceeded. Thus, for these very large units it is necessary to use a 4,160-volt auxiliary power system. By using separate transformers to supply each 4,160-volt bus, the interrupting duty of the 4,160-volt circuit breakers can be kept to a minimum so that less expensive switchgear can be used.

In some cases in which 2,400-volt auxiliaries could be used, the saving in switchgear cost by using 4,160-volt auxiliaries almost balances the extra cost of 4,160-volt motors. If it is thought that future units in the station will

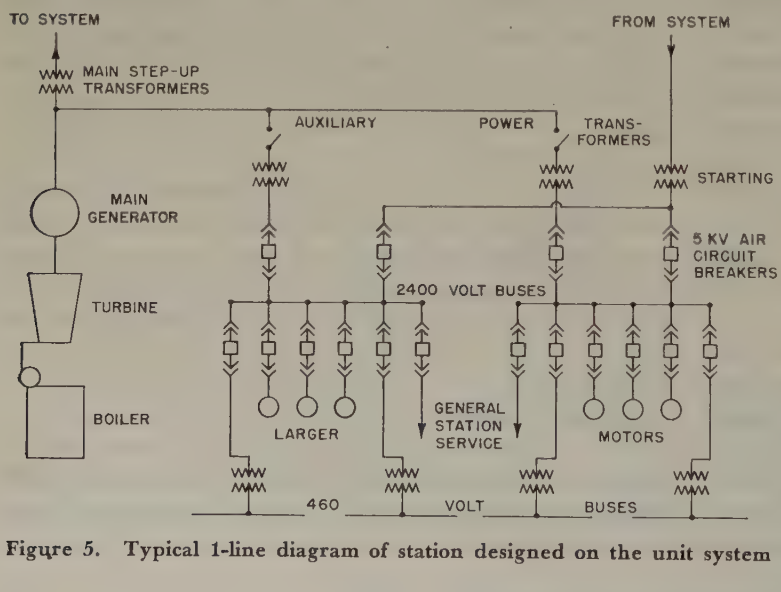

Figure 5. Typical 1-line diagram of station designed on the unit system

be of larger size, it may be advantageous to use 4,160-volt auxiliaries on the first units even though a 2,400-volt system could be used.

Efficient operation and better control of large generating units, particularly in times of emergencies, has required the development and use of a large number of automatic controls. The availability of these automatic control devices has made it possible to centralize the control of one or more boiler-turbine-generator-transformer units at one location in the station. This development has resulted in important savings in operating personnel. As the cost of providing centralized control is to a large extent independent of the size of generating unit being controlled, it can be justified more readily on large units than on smaller units. For this reason it can be expected that all large generating units will have some form of centralized control.

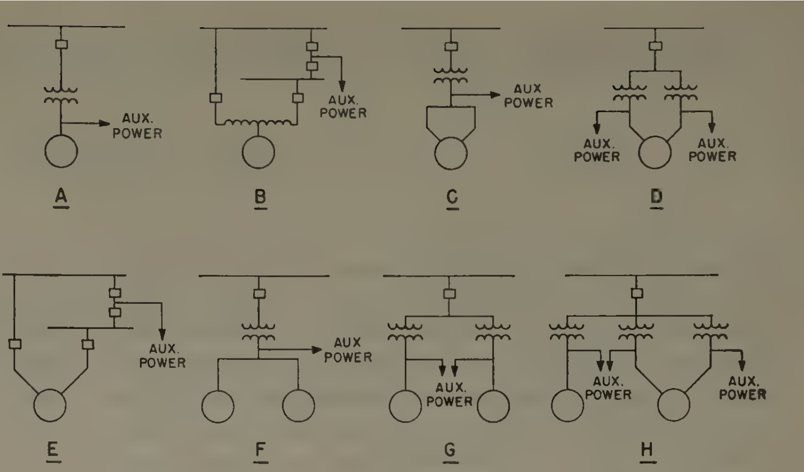

Figure 6. Typical connections to the system for various types of large generating units. (A) 1,800- or 3,600-rpm single-winding generator. (B) 1,800- or 3,600-rpm single-winding generator with duplex reactor. (C) 1,800-rpm generator with two sets of bushings. (D) 1,800-rpm double-winding generator. (E) 1,800-rpm double-winding generator. (F) Cross-compound set bussed at generator terminals. (G) Cross-compound set bussed on high side of step-up transformers. (H) Cross-compound set with double-winding 1,800-rpm generator for low-pressure turbine

CONCLUSIONS

1. Within the size range considered in this article, substantial savings in investment cost per kilowatt of generating capacity can be realized by the use of larger generating units.

2. As unit size increases there is a direct and proportional reduction in the operating cost per kilowatt-hour generated.

3. Increase in unit size with fixed steam conditions does not result in any appreciable reduction in station heat rate. However, the extra cost of using maximum steam temperatures and pressures and using the reheat cycle can be justified more easily in the larger generating units.

4. As system sizes increase and more interconnections between systems are installed, there will be a continued trend to the use of larger generating units unless the installed cost per kilowatt increases sufficiently to offset the reduction in operating cost obtainable or until the use of larger units results in an appreciable increase in reserve capacity required.

5. Until operating experience has been obtained on the large 3,600-rpm tandem-compound turbine generators now being designed, further demands for still larger generating units can be met conservatively by the use of cross-compound sets involving equipment on which operating experience already has been obtained.

6. As the generator unit size increases, the generator voltage should be selected on the basis of the most economical and best generator design rather than on any arbitrary standard.

7. Wherever possible, large generating stations should be designed on the unit system to avoid costly steam and electric interconnections and to eliminate the need for switchgear at generator voltage.

8. As the size of generating units increases with a consequent increase in the amount of auxiliary power required, the use of 4,160-volt auxiliary power systems will tend to increase.

9. As the cost of providing centralized control is practically independent of the size of generating unit, its use can be more easily justified as the size of units increases.

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Salt Spray Tests Exposure Resistance

A small aircraft motor is subjected to a continuous salt spray at the Westinghouse Electric Corporation's small motor division, Lima, Ohio. Although the equipment may never encounter such prolonged exposure in actual use, the test helps engineers determine which materials and designs can withstand best the effects of salt water

The 3-Phase Oscilloscope as an Harmonic Analyzer

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THE DISTINGUISHING feature of the 3-phase oscilloscope is its deflection system which provides deflections along three axes separated 120 degrees in space. When sinusoidal 3-phase currents flow in such a deflection system a rotating flux field of constant magnitude and constant angular velocity is produced as in a 3-phase induction motor. The flux field intensity is proportional to the maximum instantaneous current and the rate of revolution is equal to the frequency. This rotating magnetic field causes the beam spot of the cathode-ray tube to describe a circle having a diameter proportional to the current magnitude.

When nonsinusoidal currents flow in the deflection coils, the screen pattern will no longer be circular. The various frequency components produce independent revolving flux fields if the currents at any given frequency are in the proper 3-phase relationships to each other. The simplest case occurs when only two frequencies are present. Graphically, the rotating field vectors may be combined in the usual manner. The harmonic field vector may be considered to rotate around the outer end of the fundamental vector at the same time that the latter is rotating.

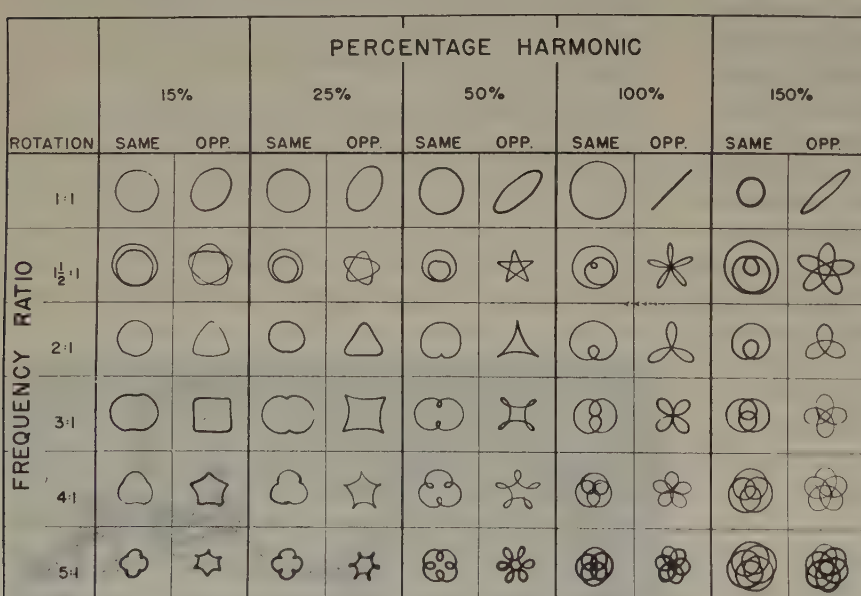

Figure 1. Screen patterns produced by combining 3-phase fundamental and harmonic voltages of different order, varying percentages, and with same and opposite phase rotation

The action of the fundamental as a circular sweep eliminates the fundamental from consideration in the shape of the pattern. With a conventional oscilloscope using a linear time sweep, the shape of a complex wave consisting of a fundamental and a single harmonic depends on the relative phase positions of the two components However, on the 3-phase oscilloscope, phase changes merely cause a slight rotation of the pattern. When more than two components are present, this advantage disappears.

Experimentally produced patterns of various combinations of harmonic orders and percentages appear in Figure 1. Harmonic percentage for these simple cases may be calculated readily from measurements of the screen pattern. The maximum radius R represents the sum of the absolute values of the fundamental and harmonic vectors, while the minimum radius r represents their difference. The ratio of the harmonic to fundamental is equal to the ratio $(R-r)/(R+r)$. The formation of loops or nodes on the pattern also offers an indication of the percentage harmonic. The smallest percentage which will produce the required cancellation of linear velocities of the revolving vectors is $100/n$ per cent, where n is the frequency ratio or order of the harmonic.

The order and phase sequence of the harmonic with respect to the fundamental are shown by the number and position of the loops on the pattern. When loops form on the outside of the pattern, phase rotation of the harmonic is opposite to that of the fundamental and there are $n+1$ loops. When the loops are on the inside, phase rotation is the same and there are $n-1$ loops.

In symmetrical 3-phase circuits, the waveform of each phase current or voltage is the same as the others except for the customary 120- or 240-degree phase shift. However, a 120-degree phase shift for the fundamental corresponds to a $120k$-degree phase shift for the kth harmonic.

Consequently, the phase sequence of the harmonic may be reversed from that of the fundamental or reduced to zero. The sequence of any harmonic in a symmetrical system may be determined by the application of the following rule: If $n=1+3m$, the sequence is positive; if $n=2+3m$, the sequence is negative; and if $n=3m$, the sequence is zero. $(m=0, 1, 2, 3, \ldots)$. Zero sequence harmonics do not appear on the 3-phase oscilloscope since they do not have the necessary 3-phase relationship.

Digest of paper 51-381, "The 3-Phase Oscilloscope as an Harmonic Analyzer in Power Systems," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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New Principle for 60-Cycle A-C Network Analyzers

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THROUGH THE USE of a new design principle,[1] first used in the a-c analyzer purchased by the University of Kansas and since improved, it has been possible to use reactors having a Q value (ratio of reactance to equivalent resistance) as low as 7.8 to simulate the reactance of transmission lines. Although these reactors have a low Q, their electrical characteristics are identical to those possessing a Q of 25 and used in nonphase-shift analyzers. Reactors having a Q of 9.3 may be used to simulate the reactance of generators which otherwise require a Q of 50.

Since the weight of the active material required in a reactor decreases approximately as the third power of its Q value—all performance characteristics and type of construction remaining unchanged—a reduction of its Q from 25 to 7.8 reduces its weight to 3 per cent. The generator-type reactor weight is reduced to 0.7 per cent of one having a Q of 50.

A reactor having a Q of 11.4, corresponding to an angle of 85 degrees, when used in a 5-degree phase-shift analyzer, performs exactly as though its losses were zero—an apparent infinite Q. Each reactor circuit of a 5-degree phase-shift analyzer has an impedance angle of exactly 85 degrees and is adjusted to this value by using a low-value series resistor. This reactor, which has a Q of approximately 11.9, weighs 10.8 per cent of one having a Q of 25, and 1.4 per cent of one having a Q of 50. Thus, when a line-impedance unit reactance knob is set to X per cent ohms, the analyzer circuit contains X per cent ohms' impedance having an angle of 85 degrees instead of 90 degrees.

Each resistor, excepting the three smallest of a line-impedance unit, is paralleled by an appropriate amount of capacitive reactance, thereby obtaining an impedance of like value but having a leading angle of 5 degrees. When a line-impedance unit resistance knob is set to R per cent ohms, the analyzer circuit contains R per cent ohms' impedance having an angle of -5 degrees instead of zero degrees.

Because 85-degree analyzer impedances are used to represent system reactances and -5-degree impedances for system resistances, when the knobs of an analyzer line-impedance unit are set to R per cent ohms and X per cent ohms, identical values to those of a system line impedance, the analyzer unit will contain a per cent impedance equal to but having an impedance angle 5 degrees less than that of the system line.

The zero loss characteristic of the reactor circuits has made possible an improved load unit. The knobs of this new type unit are set to the same per cent power and reactive power as that of the system load. No reduction in the settings of the kilowatt knobs is required to compensate for reactor losses.

The impedance phase shift of the capacitive-reactance units is obtained by advancing the voltage applied to each of their circuits by 5 degrees. This advancement results from the method used in connecting the capacitors into the network, the return connection from each unit being made to a common bus, the capacitor bus, instead of to the neutral bus. A regulation-type generator unit is connected between this bus and the neutral, causing a voltage displacement between them. Thus, the voltage applied to each capacitive-reactance unit is the vector sum of that of the capacitor-bus generator and the particular value bus-to-neutral voltage of the network bus to which the capacitor is connected. The generator is adjusted in such a way that this resultant voltage will cause a current to flow through a selected capacitance unit that will be of the correct magnitude but that will have a phase-angle relation with the capacitor's bus-to-neutral voltage of 95 degrees, leading. Means are provided for the rapid obtainment of this adjustment.

Since each analyzer element has a per cent impedance that is equal in magnitude to but differs by -5 degrees in impedance angle from that of its system counterpart, the per cent current in each analyzer circuit is equal to and leads by 5 degrees the per cent amperes in the corresponding system circuit. In order that the correct measurement of watts and reactive volt-amperes may be obtained despite this current advancement, the currents in the potential circuits of these instruments also are advanced by 5 degrees; this is accomplished by changing the impedance angles of the potential circuits by -5 degrees.

An impedance base of 4,000 ohms is used for the 60-cycle impedance-phase-shift analyzer. A relatively high impedance base may be used for low-frequency analyzers without the extraneous voltages caused by capacitive and inductive couplings becoming a problem in measurement accuracy. A reduction in the analyzer capacitor sizes used for the representation of system capacitances results from the use of the 4,000-ohm base. The largest capacitor in an adjustable capacitance unit has a value of 0.133 microfarad, and 3.32 microfarads is the equivalent of 500 per cent system reactive power.

The power supply for the 60-cycle analyzer is obtained from a 3-phase bank of magnetic-stabilizing transformers which provides a nonfluctuating voltage supply. The primaries are connected directly to a commercial 3-phase supply line. A filter network is used to obtain a sinusoidal voltage.

Digest of paper 52-19, "A New Principle Is Employed for 60-Cycle, A-C Network Analyzers," recommended by the AIEE Committee on Computing Devices and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

E. B. Phillips is with the University of Kansas, Lawrence, Kans.

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An Evaluation of Butyl Insulation for Outdoor Instrument Transformers

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MEMBER AIEE

H. E. CRABTREE

Another step in the progress of measurements has been made with the successful application of molded butyl compound as insulation on a new instrument transformer for indoor and outdoor use on secondary circuits. The investigations concerning the use of this compound for outdoor use are described in this article.

IT HAS BEEN common practice among all manufacturers of instrument transformers to use two general types of insulation, determined by the operating voltage involved. Up to about 15,000 volts, a dry type or compound impregnated construction is employed. Above that voltage, liquid-filled designs are used. For outdoor service, the insulated transformer is placed in a waterproof metal casing with porcelain bushings.

With the development of a molded butyl insulation, a new dry type material was added to those available to design engineers.[1] This synthetic elastomer possesses many outstanding advantages over other dry type insulations and is being used successfully and to an increasing extent on a line of 5,000-volt indoor metering transformers.[2] This transformer is illustrated in Figure 1.

The use of this molded butyl compound has now been extended to include outdoor as well as indoor service. The first indoor-outdoor transformer, for low-voltage service, is illustrated in Figure 2.

Butyl compound has several outstanding characteristics that make it suitable for an outdoor insulation: low moisture absorption, good corona and sunlight resistance, excellent adhesion to copper, very low power factor, and good resistance to mechanical damage.

By the use of butyl compound, large expensive cases of metal and porcelain are no longer necessary on low-voltage outdoor transformers. In addition, the compact designs made possible by molded insulation result in a universal low-voltage transformer, small enough to meet the standardized mounting dimensions for indoor service and completely waterproof for outdoor service. Figure 3 compares the new butyl design with the conventional outdoor metal-porcelain construction and a typical indoor transformer with asphalt-impregnated insulation. Indoor-outdoor designs offer definite possibilities for standardization to both the user and the manufacturer.

Butyl gum is a synthetic elastomer (GRI) developed just prior to and during World War II. The gum for electrical usage is composed of 97 to 99 per cent polyisobutylene, plus 1 to 3 per cent isoprene necessary for vulcanization. The polyisobutylene molecule, since it has no double valence bonds, is in an exceedingly stable molecular condition.[3–5] This results in unusually good chemical stability and resistance to oxidation. To make the gum suitable for molded transformer insulation, it is mixed with several other ingredients. These fillers, plasticizers, and vulcanizing agents make up about 60 per cent of the final compound.

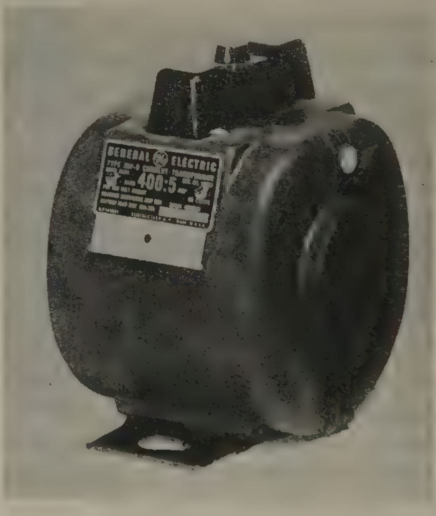

Figure 2. Butyl-molded current transformer for indoor and outdoor metering service

Figure 1. A 5,000-volt butyl-molded current transformer for indoor metering service

Essentially full text of paper 51-374, "Evaluation of Butyl Insulation for Outdoor Instrument Transformers," recommended by the AIEE Committee on Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Figure 3. Butyl-molded indoor-outdoor current transformer (center) shown with the conventional asphalt-paper porcelain-steel outdoor type and the conventional asphalt-paper indoor type

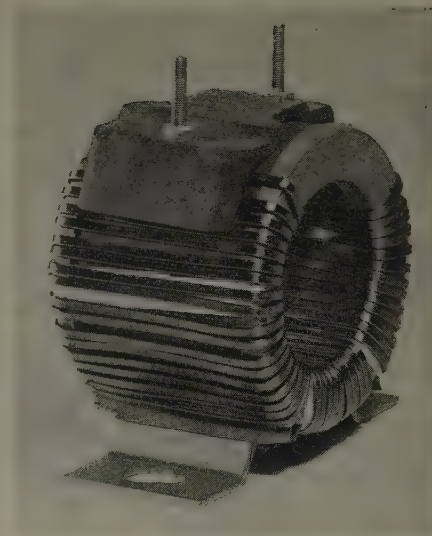

Figure 4. Indoor-outdoor transformer insert ready for butyl molding

In the molding process, the uncured compound is forced into a heated mold, which forms the outside contours of the transformer and also locates the core with windings, terminals, and mounting base. Figure 4 illustrates the insert ready for molding. When filled, the loaded mold is heated under closely controlled conditions to cure, or vulcanize, the butyl into a solid, homogeneous mass, possessing excellent insulation properties.

When cured, the transformer is removed practically complete, needing only to have excess molding flash removed and the secondary hardware and name plate installed to make it ready for final test and shipment.

PROPERTIES OF BUTYL INSULATION

Once butyl had been proved as an indoor transformer insulation, the next consideration was its suitability for outdoor use as well. To determine the possibilities, its properties were evaluated in terms of the performance required and the various conditions that such an insulation would be required to meet.

The properties of butyl compound required for outdoor use were determined by test. It was found that molded butyl is excellent for certain outdoor applications.

An effective waterproof casing made of butyl molded as an integral part of the transformer has been developed. The butyl casing is sealed to the terminals and other metal parts during molding to provide watertight seals for outdoor usage. The result is a butyl casing that performs all of the functions of an outdoor housing made of metal and porcelain.

The resistance of butyl to the penetration of moisture was determined by the use of water-immersed samples of various known thicknesses. Molded and sheet samples were used, as shown in Figures 5 and 6. The molded samples contained wire mesh electrodes, so that any moisture that penetrated the butyl layer would distribute itself and be detected readily. These samples were immersed in water and then tested at intervals of time. Tests of power factor and capacitance were made to determine the rate and degree of moisture penetration through the layer of molded butyl.

The results of these tests are shown in Figures 7, 8, and

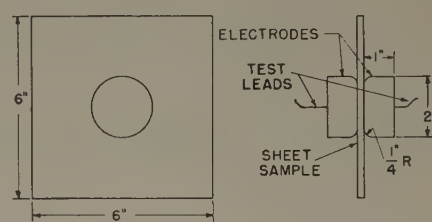

Figure 5. Water penetration sheet sample. These were aged in water, then tested in air for capacitance and power factor

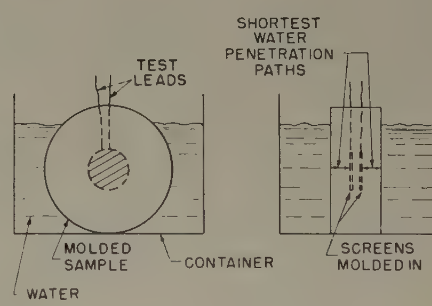

Figure 6. Water penetration molded sample. Samples aged in water were tested in air for capacitance and power factor

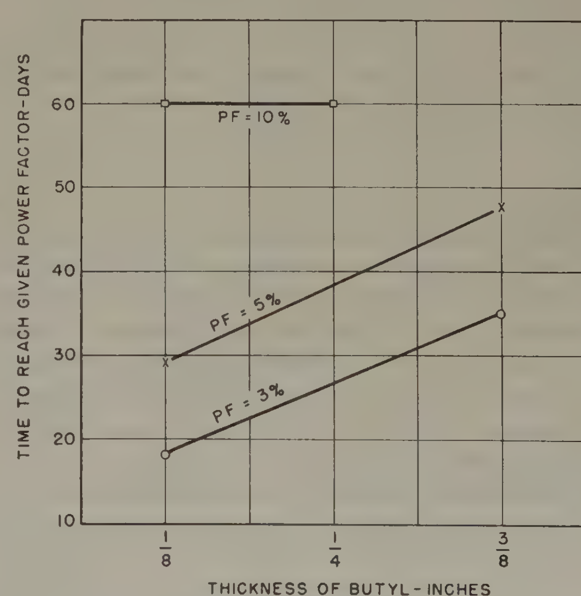

Figure 7. Water penetration of molded butyl at 75 degrees centigrade

9. For a 1/8-inch thick layer of butyl, a period of 29 days' immersion at 75 degrees centigrade was required for an appreciable change (5 per cent) in power factor. In water at room temperature (approximately 25 degrees centigrade) there was no change after immersion for 55 days. After being immersed in water for a sufficient time to change the power factor, recovery rate by drying was very rapid. This is shown in Figure 9.

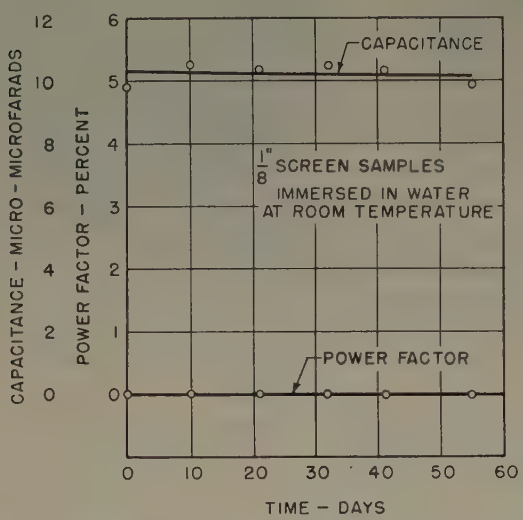

Figure 8. Water penetration of molded butyl at room temperature

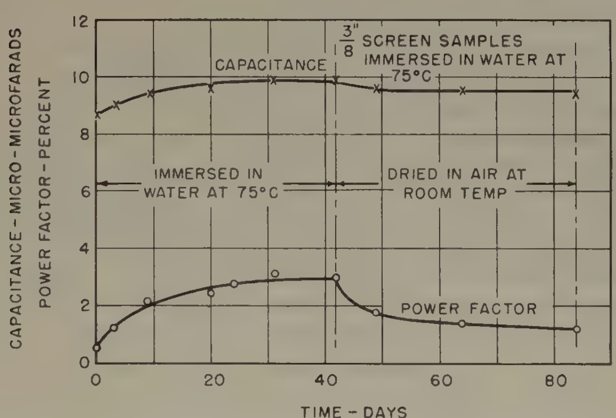

Figure 9. Water penetration at 75 degrees centigrade and drying at room temperature of molded butyl

To provide a waterproof casing for the transformer, the butyl required for insulation on the outside surfaces was increased. An added thickness of about 1/8 inch is considered adequate to prevent moisture penetration.

Resistance to weathering was found to be excellent as determined by accelerated weathering tests made on both material samples and transformer samples. After extended actual weathering in an industrial atmosphere, transformer samples were operating satisfactorily and showed no adverse effects when tested. On an actual outdoor service installation in exceptionally corrosive atmospheres, trial transformers are still operating satisfactorily after more than a year's service.

Mechanical tests made on samples of butyl compound strips showed that the hardness and elasticity improved, as shown in Figure 10, after aging for 12 months under various conditions. Examination of sample transformers after 3 years of outdoor aging showed that the butyl insulation was in excellent mechanical condition.

To prevent the possibility of moisture entering the transformer, a method was developed for sealing the molded butyl to the protruding metal parts of the transformer. Samples of the seal tested under a pressure of 10 feet of water for a continuous period of 14 days displayed no signs of leakage.

One of butyl's most important properties which had to be evaluated was its resistance to voltage creepage. Creepage is the phenomenon of leakage current flowing along a surface from one electric potential to another. On a current transformer, there is a considerable potential difference from the primary to the secondary winding and from the primary to ground. Because of the exposed terminals, the voltage creepage characteristics are of considerable importance.

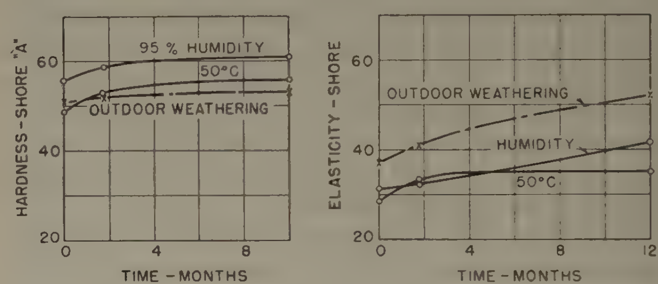

Figure 10. Mechanical properties of molded butyl. Hardness and elasticity versus aging time under various aging conditions

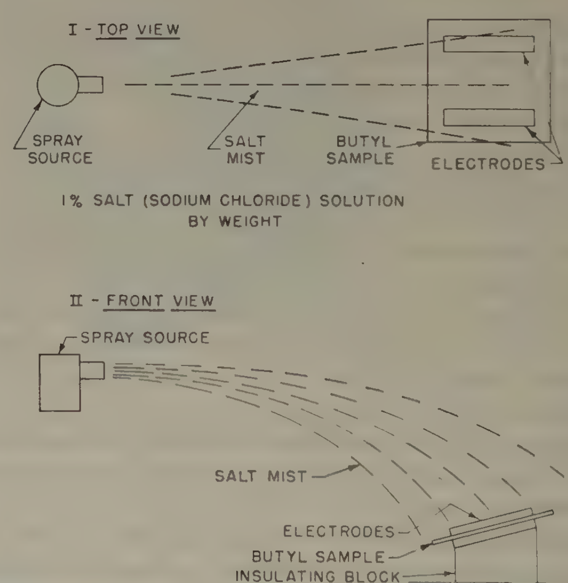

Figure 11. Test setup for determining surface voltage creepage

In this investigation, the critical data have been obtained to utilize the creepage characteristics for the utmost benefit in the finished transformer design.

The test method consisted of applying voltage between

two parallel bar-type electrodes placed on the surface of the sample. The butyl surface was inclined approximately 15 degrees to the horizontal and subjected to a salt mist. This is shown in Figure 11. The 15-degree slope was used in the tests because it represented the worst practical operating condition, since transformer surfaces are designed to have a slope of greater than 15 degrees. A salt solution of 1 per cent sodium chloride by weight was used.

The presence of creepage was determined by viewing the creepage current on an oscilloscope. Figure 12 shows the electric test circuit used. The creepage was shown on the oscilloscope as very short-time increases in current or as a change in current during a single cycle of applied voltage. The detection of creepage is shown in Figure 13. This test method provides a sensitivity of detection that is not possible by direct visual perception of creepage.

Using this method of testing, the worst creepage condition to be expected during the normal service of outdoor transformers was determined. It consists of a very dirty surface with a water mist directed upon it. Dirt collected in an industrial atmosphere was used for this test. This condition was very unstable, since the dirt washed off rapidly, causing the creepage to stop. It was found that a salt mist was an equally bad condition and, in addition, was stable and reasonably repeatable. The salt spray therefore was adopted as a practical test method, since it was equivalent to the typically poor condition of dirt from an industrial atmosphere plus a water mist.

Tests were made to determine at what minimum voltage creepage occurred. It occasionally started at a minimum voltage gradient of 450 volts per inch under the test conditions used. Creepage usually started at a voltage gradient above 800 volts per inch. Visual creepage occasionally occurred at a minimum voltage gradient of 800 volts per inch. Visible creepage usually started at a voltage gradient above 900 volts per inch.

The effects of high surge voltages added to the impressed 60-cycle voltage were investigated. Tests show that there is no change in the creepage start voltage due to the addition of voltage surges. Flashover or creepage that occurs during voltage surges does not continue after the surge and does not cause damage to the surface.

Since creepage starts at a relatively low voltage, tests were made to determine its damaging effects. At a potential gradient of 2,000 volts per inch across the surface, visible creepage occurred and caused visible damage after 80 hours of continuous operation. A potential gradient of 1,000 volts per inch produced creepage that was detectable with the test equipment. After 80 hours of continuous operation, some damage had occurred and sparking was visible occasionally. At 300 volts per inch, creepage was neither visible nor detectable on butyl and produced no effect after 100 hours of continuous operation under the salt mist.

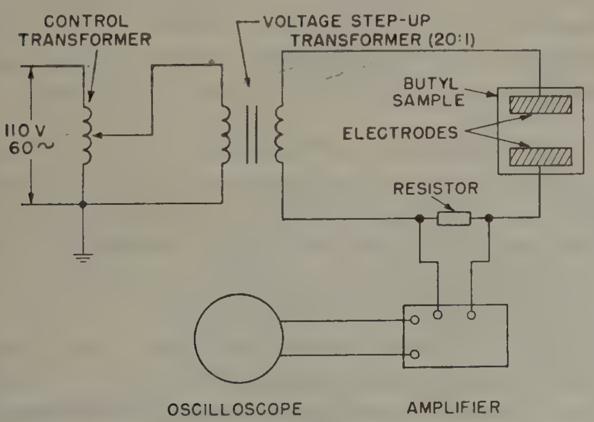

Figure 12. Electric circuit for the creepage test

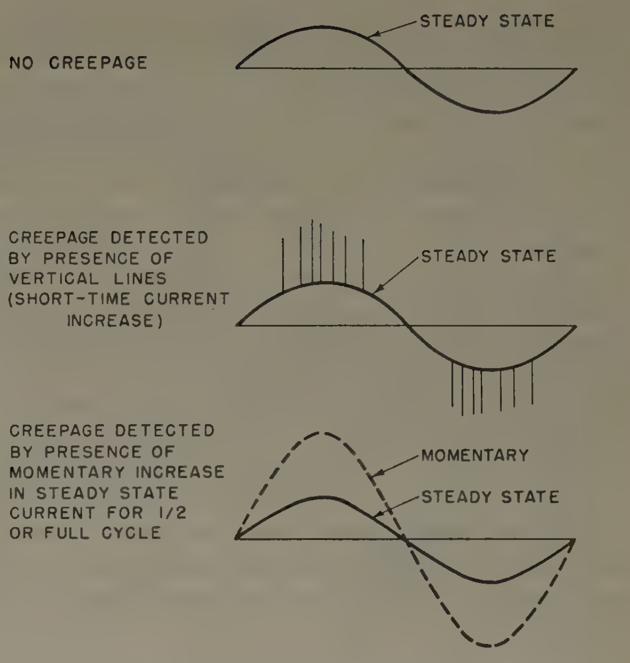

Figure 13. Detection of creepage leakage current between electrodes as seen on an oscilloscope

It was concluded that a satisfactory butyl outdoor design must operate at a sufficiently low surface voltage gradient to prevent creepage from occurring. This has been accomplished in the transformer design by allowing sufficient distance between terminals and other parts. A design value of 200 volts per inch maximum creepage gradient has been used on the first indoor-outdoor design. This represents conservative design based on the characteristics of the present material. It is anticipated that progress in the design of higher voltage ratings will result from the improvement of this characteristic of molded butyl compound.

The effects of aging on creepage characteristics were satisfactory for the outdoor use of this material at low voltages. Samples that had been aged for 3 years under various conditions were tested for creepage start voltage. The results of these tests are:

Aging Condition	Aging Period	Absolute Minimum Creepage Start Voltage, Volts per Inch
90 per cent humidity, 30 degrees centigrade	3 years	360
75-degree centigrade oven	3 years	350
Outdoor exposure	6 months	400
Room temperature	6 months	450

Tests made on sheet samples that had been subjected to

accelerated aging in a weatherometer and a 100-degree centigrade oven showed that butyl has good resistance to creepage. Samples subjected to accelerated aging compared reasonably well with samples aged at room temperature. The minimum start voltage increased approximately 25 per cent during the 62-day accelerated aging period both for the accelerated samples and for the normally aged samples.

The electrical and chemical properties of this special transformer butyl compound have proved to be satisfactory for use as both indoor and outdoor insulation. These properties are shown in Table I.

The general physical properties of butyl are excellent for its use as an outdoor insulation. It is on the basis of these properties that this material offers many advantages over old materials. By the elimination of metal-porcelain casings and asphalt-paper insulation, many design and manufacturing simplifications are made possible. These result in standardization and additional improvements in the finished transformer.

TRANSFORMER DESIGN

It was necessary to utilize the various properties of butyl in a final transformer design to meet the requirements of excellent performance under adverse operating conditions. Some of the design details used to obtain the maximum possible benefit from this material are shown in Figure 14.

The outdoor transformer in which this new insulation is used has been designed very carefully to utilize fully the superior characteristics of molded butyl. This has resulted in the successful accomplishment of an entirely new concept in design, namely, an indoor-outdoor instrument transformer.

The mechanical construction combines strength with small size and ease of molding. The high-permeability

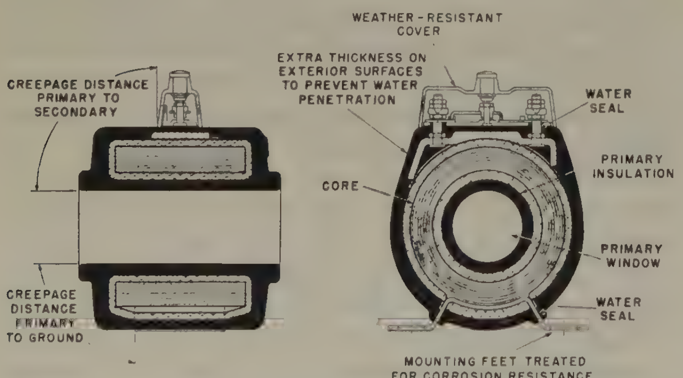

Figure 14. Some design details using butyl as an outdoor insulation

silicon steel core is fastened to the base by a welded steel strap, providing excellent support for molding and for ruggedness in service. The construction is shown in Figures 2, 4, and 14.

This new transformer combines several important features of both indoor and outdoor current transformers. In addition to being suitable for outdoor use without external housings, it has features that make it excellent for indoor use.

The secondary terminals are located on top for maximum accessibility. The over-all size is small for convenient use in limited space. This transformer essentially meets all

Table I. Important Properties of Butyl Compound for Use as an Indoor or Outdoor Instrument Transformer Insulation

Electrical Properties	
Dielectric strength (minimum)	400 volts per 0.001 inch
60-cycle power factor [American Society for Testing Materials (ASTM) *D150*]	0.3–0.8 per cent
Dielectric constant (ASTM *D150*)	2.5–3.5
Arc tracking (ASTM *D495–42*)	130 seconds
Volume resistivity	10^{15} ohms per cubic centimeter
General Physical Properties	
Tensile strength (ASTM *D412*)	700 pounds per square inch
Elongation	680 per cent
Hardness (shore "A")	45–60
Elasticity (shore)	38
Abrasion resistance	good
Specific gravity	1.3
Specific heat	0.36
Thermal conductivity	6.4×10^{-4} calories per second per cubic centimeter per degree centigrade
Flexing resistance	excellent
Resistance to mechanical damage	excellent
Chemical Properties	
Corona resistance	good
Flame resistance	good
Ozone resistance	good
Sunlight resistance	good
Resistance to attack by:	
Transil oil	fair
Sulphuric acid	good
Sodium hydroxide	good
Salt spray	good
Miscellaneous Properties	
Suitability for molding	good

requirements of the Edison Electric Institute specification *MS-2* for low-voltage metering transformers. It fits in the same space and, with an adapter, may be used on the same mounting holes. This design offers the advantages of flexibility, since it may be used with either a cable or a primary bar passing through the primary window, and for certain current ratings may be used for 3-wire single-phase metering applications.

A careful utilization of the superior properties of molded butyl has made possible many improvements in the finished high-accuracy transformer. Outstanding among these are high thermal rating, small convenient size, and long-time stability of insulation properties. This contribution to the development of insulating materials now offers the many economies of a standardized indoor-outdoor current transformer.

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Industrial Standards for Defense Production

R. C. SOGGE
MEMBER AIEE

THE SUBJECT OF industrial standards for defense production is one which is important to the electrical industry and to all of us as American citizens and taxpayers. As businessmen we realize that unless the electrical industry produces defense equipment in sufficient quantities to defend America successfully, there may not be any business for any of us; and also we are proud to note that the equipment produced by the electrical industry is becoming more widely used and more important to our defense program.

At the present time, defense production is a very substantial part of the total output of the electrical industry and the standards which guide defense production can affect seriously the ability of our industry to produce all of the equipment we are going to need. In some of the larger companies, upwards of 25 per cent of current business is now for direct defense production and possibly another 25 per cent is going to customers who in turn are building new factories, new power plants, or equipping their present factory space for defense production.

After emphasizing the increasingly important role the electrical industry is playing in the production of defense equipment, the author points out the necessity for continued co-operation between the military and industry in developing proper standards.

The proper use of industrial standards can aid in increased production, contribute to shorter delivery, help to conserve critical materials, and assist substantially in getting lower costs—and our country needs all of these. Many examples have recently been collected which show the substantial benefits realized by standardization and simplification programs by member companies of the American Standards Association (ASA).

INDUSTRY AND MILITARY REQUIREMENTS

BUSINESS CONTRACTS between industrial companies incorporate industrial standards because they aid in a clearer and more definite understanding of just what our customer expects us to build, how it is to be tested, and when we get our money. Raw materials are purchased by the electrical manufacturing companies with the aid of such industry standards as those of the American Society for Testing Materials, American Iron and Steel Institute, Society of Automotive Engineers, and ASA. The sale of electric equipment is usually covered by definite specifications which incorporate the standards of industry, such as those prepared by AIEE, National Electrical Manufacturers Association (NEMA), Radio-Television Manufacturers Association (RTMA), Institute of Radio Engineers, and ASA.

It is appreciated that defense production for a strictly military purpose of necessity may be different from products for commercial use and must be manufactured to meet more rigid requirements. In certain branches of the Service special emphasis must be placed on light weight or a compact design which will use little space. In other branches, the products must be especially sturdy to withstand shocks. These requirements will dictate the use of special materials and stress or thermal limits not applicable to commercial production. These differences of application are understandable. Where lives are at stake, the best is none too good.

But there are many items of defense production where the end use is the same as in industry; and for the production of such items there are many industrial standards which should be considered carefully as useful tools for the most efficient and economical defense production. Before we discuss what is not being done, we should recognize the fact that much has been accomplished to promote co-ordination and unification of standards for industry and military needs. I understand that the American Ordnance Association Committee has achieved notable results in the preparation of specifications for items of munitions which permit ready adoption by industries with a minimum of expense and confusion.

The co-operation between branches of the military and Aircraft Industries Association is producing excellent results. I am more familiar with the program of the Armed Services Electro Standards Agency (ASESA) at Fort Monmouth, N. J., which is reviewing proposed standards with RTMA and NEMA as well as with the industrial companies which produce the equipment. In many cases ASESA already has incorporated a good many of the provisions of industrial standards, and then comments and suggestions are invited from industry. The resulting standard will require a minimum change by industry in providing the equipment covered by such specifications.

IMPORTANCE OF STANDARDS

THE EXPERIENCE IN each war has demonstrated that standards are of major importance in national defense. In many cases, representatives of the Services were stationed

Full text of an address presented at the Second National Standardization Conference of the American Standards Association, New York, N. Y., October 22–24, 1951.

R. C. Sogge is with General Electric Company, Schenectady, N. Y.

at industrial plants and worked with industry as a part of the organization. Every Government contract specifies in detail each part of the equipment, and in many cases how it is to be manufactured. When standards are different from those with which industry is familiar, it takes considerable time to make adjustments in routine, retrain the organization, and order special materials and components. All of this takes time and money, and we must avoid as much of this as possible by closer co-operation and understanding during peacetime. The subcontracting phase of production is especially difficult when industrial standards are not applicable.

Human nature being what it is, it is understandable that there are some in military who have the attitude that the Government should dictate to industry and, likewise, there are some in industry who feel that Government should take what industry makes without change. The development of proper industrial standards is a co-operative activity, and barriers which have prevented most effective co-operation should be studied and overcome. Defense production will benefit greatly from co-operatively developed standards for screw threads, unification of bolts and nuts, cylindrical fits, ball and sleeve bearings, welding apparatus, color codes for piping, color codes for lubricants for machinery, electric measuring instruments, capacitors, rectifiers and other components, and drawings and drafting-room practice.

It was disappointing to learn from the British industrialists that a meeting on Drafting Standards was held in Ottawa, Canada, last year, attended by British military and industrialists, Canadian military and industrialists, United States military but not industry. Certainly drafting standards, which are a basic part of the engineering and manufacturing operations in many companies, are a type of industrial standard on which there should be a closer understanding. With the many drafting practices that are required now, it not only necessitates additional expense to change drawings but there are also the adjustments which must be made in company practice, constant retraining of employees, and there is a greater exposure to mistakes.

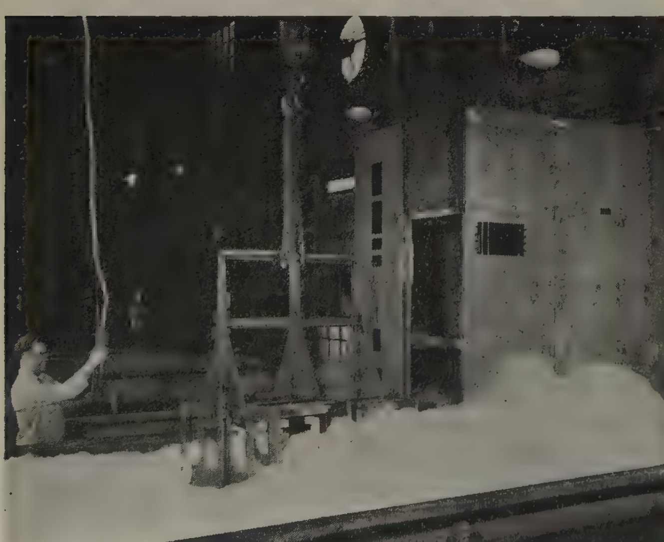
Take such an obviously simple question as the numbering system to be used on drawings. I find in some cases that two numbers are permissible on the drawing but only the Government number is permitted on the manufactured part. In other defense production contracts, the manufacturer is permitted to use his own number both on the drawing and on the parts. But there are other contracts on which it is mandatory that a Government number be used on the drawing and on the part produced from that drawing. It is possible under these conditions that an interchangeable part will be produced with three different part numbers.

When we do have a unification in standards it is necessary that there be a prompt revision in the procurement specifications. At the present time, for example, most of the Army-Navy drawings on hardware, such as screws, still continue to call for the old class-*2* or class-*3* tolerance while industry is now turning out products with the new class-*2A*, *2B*, *3A*, and *3B* fits. It is my understanding that the different branches of the Service have agreed to the revised standard and that the Bureau of Standards has revised its *H28* Handbook, but that many of the individual Service specifications and drawing references continue to lag the industry.

GOVERNMENT AGENCIES AND ASA

THE DEVELOPMENT AND adoption of common industrial standards presents a great opportunity for both the military and industry. A real effort should be made to promote plans for working together to our mutual advantage. Some of these industrial standards will have such a broad application that they should be American Standards evolved under the procedure of the American Standards Association. In the work of many ASA Sectional Committees representatives of several Government agencies are participating, but recently they have been handicapped in being advised that they may participate only on a liaison basis. The development and approval of industrial standards are so important to both military and industry that it would seem desirable that suitable provision be arranged so that representatives of these important Government agencies will have the same status as representatives from national standards organizations of industry which are members of ASA. I am sure that the electrical industry would appreciate the assistance which can be given by these representatives in working out satisfactory standards so that we will be in an even better position to handle defense production on an efficient basis.

Switchgear Made Rust-Resistant



Lower maintenance cost, longer life, and improved appearance are provided by Bonderizing metal-clad switchgear manufactured by the Westinghouse Electric Corporation. Here circuit-breaker frames and metal switchgear housings enter the alkaline bath, first of a series of five baths in 11,000-gallon tanks for protection against rust and corrosion. To preserve the full effectiveness of Bonderizing, a patented rust-resisting treatment, the units are air-dried and sprayed with a primer coat

Joint AIEE-IRE Computer Conference in Philadelphia Attracts Over 900

More than 900 engineers, scientists, and mathematicians attended the Joint AIEE-Institute of Radio Engineers (IRE) Computer Conference held in Philadelphia, December 10–12, 1951. This meeting afforded the first opportunity for manufacturers and users of large-scale digital computing equipment to exchange information on results obtained from completed machines. Ten computers were described in some detail, including two machines located in Great Britain.

TECHNICAL SESSIONS

Following a keynote address on Monday morning by Dr. W. H. MacWilliams, Jr., of the Bell Telephone Laboratories, the UNIVAC System was described first by the manufacturer in a paper "The UNIVAC System" by J. P. Eckert, J. R. Weiner, H. F. Welsh, and H. F. Mitchell of Eckert-Mauchly Computer Corporation, Division of Remington Rand, Inc., and then by the user, the Bureau of Census, in the paper "Performance of the Census UNIVAC System" by S. N. Alexander and J. L. McPherson. The Burroughs Laboratory Computer was evaluated in a paper by G. R. Hoberg of Burroughs Adding Machine Company. On Monday afternoon inspection trips were made to Burroughs Research Division, Moore School of Electrical Engineering, University of Pennsylvania, Eckert-Mauchly Division of Remington Rand, and Technitrol Engineering Company. On Monday evening Dr. S. N. Alexander of the National Bureau of Standards delivered an address, "The Significance of Electronic Computers to Science and Management," before a joint meeting with the Philadelphia Sections of AIEE and IRE.

On Tuesday the International Business Machine Card Programmed Calculator was discussed by J. W. Sheldon and L. Tatum of International Business Machines Corporation. Dr. H. Goldstine of the Institute for Advanced Study at Princeton made some brief comments on the family of machines which have evolved from the Institute's computer program. This was followed by a paper on the ORDVAC by R. E. Meagher and J. P. Nash of the University of Illinois describing one of the machines of this family in detail. On Tuesday afternoon "The ERA 1101 Computer" was discussed by F. C. Mullaney of Engineering Research Associates. G. E. Poorte of United States Naval Proving Grounds, Dahlgren, Va., described applications of the Mark III Calculator from the user's point of view in his paper, "The Operation of the Mark III Calculator." T. Kilburn and B. W. Pollard described the English University of Manchester computing machine from the user's and manufacturer's viewpoints respectively in a 2-part paper. Because of the large number of requests, extra inspection trips were scheduled for Tuesday evening.

On Wednesday R. R. Everett and N. H. Taylor of Massachusetts Institute of Technology presented their experience with the Whirlwind I Computer. M. V. Wilkes of the University of Cambridge, England, described the EDSAC, and the National Bureau of Standards Eastern Automatic Computer was evaluated by S. N. Alexander and R. J. Slutz.

A conference luncheon was held in the Benjamin Franklin Hotel. Guest speaker was Mr. Charles R. Strang, chief strength engineer of Douglas Aircraft Company. Mr. Strang gave an indication of the importance of computing equipment of all kinds in the complex engineering operations of a large aircraft company. Following the luncheon Dr. J. Felker of Bell Telephone Laboratories presented a paper on "The Transistor as a Computing Component." The conference was concluded with a Summary and Forecast by Dr. J. W. Forrester of Massachusetts Institute of Technology.

PROCEEDINGS OF CONFERENCE

The committee sponsoring this conference wanted comprehensive reports of experience on existing computers to be recorded in permanent form. Consequently a prerequisite for presentation of the papers was that a written text be made available. These written papers are more complete than the oral presentations in that they contain technical and other details which could not be presented orally because of time limitation. The papers and the discussion which followed the oral presentation will be collected in a bound Proceedings which should be available very soon. These Proceedings, which will be sold for $3.50 a copy, may be obtained either from AIEE or IRE Headquarters.

Information on Revised Membership Grades Announced by Institute

Amendments to the Constitution revising the membership grades of the American Institute of Electrical Engineers were adopted by a large majority last June. These changes affect all who then were members of the Institute as well as those subsequently applying for membership or transfer.

The Associate grade has been eliminated and those who held that grade will be listed henceforth as Associate Members. The new grade calls for higher qualifications than the former Associate grade. Those who now apply without engineering experience and qualifications will be considered for Affiliate grade if their admission would contribute to the interests of the Institute. Typical activity of Affiliates would be in the accounting, commercial, legal, industrial economic or industrial aspects of electrical engineering or electrical science. An Affiliate may apply for transfer to Associate Member grade when he has acquired the requisite engineering qualifications.

Committee members and speakers attending the Computer Conference are, left to right in the front row, J. Forrester, W. H. McWilliams, Jr., E. C. Berkeley, H. E. Tompkins, J. C. McPherson, C. R. Strang, N. H. Taylor, J. H. Howard, F. T. Maginniss, and S. N. Alexander; in the back row, left to right, are J. D. Chapline, Jr., S. E. Moore, G. Palmer, Jr., R. S. Gardner, R. D. Adams, Jr., H. H. Sheppard, and E. Lovell

Individuals holding the grade of Member continue in that grade. Applicants for admission or transfer to Member grade under the rules as revised must, however, meet higher requirements than heretofore.

Under the new constitutional provision the grade of Fellow is an honor to be acquired only through invitation of the Board of Directors. A group of five or more Members and/or Fellows may bring to the attention of the Board of Directors the achievements of a Member which they believe may warrant conferment of the grade of Fellow. Data submitted in substantiation of the proposal must give not only a well-detailed record of the electrical engineering experience of the Member but must enunciate clearly the outstanding accomplishments on which his citation for distinction could be based. Five Fellows shall be cited as references who can corroborate the claims made on behalf of the Member by those who propose his name. The Board of Examiners will review the detailed record and the responses of the Fellows serving as references and subsequently report to the Board of Directors its findings as to the qualifications shown and the merit of the distinctive accomplishments cited by the sponsors. The proposal will be returned to the sponsors to obtain the acquiescence and signature of the successful nominee.

Institute and Best Student Paper Prize Awards Announced

The Committee on Award of Institute Prizes, with J. J. Orr as Chairman, has announced the award of the Institute Paper Prizes in each of four of the five technical classes for papers presented during the period August 1, 1950, to July 31, 1951. As the General Applications Division was unable to make any recommendations, the committee approved a motion to withhold the award of prizes for papers coming within this technical division.

The papers selected for first and second prize are as follows:

Communication Division

First Prize awarded to:
A Submarine Telephone Cable with Submerged Repeaters, J. J. Gilbert, Bell Telephone Laboratories, Inc.

Second Prize awarded to:
Submerged Repeaters for Long Submarine Telegraph Cables, C. H. Cramer, Western Union Telegraph Company

Industry Division

First Prize awarded to:
Transient Response of Small 2-Phase Induction Motors, A. M. Hopkin, Northwestern University

Second Prize awarded to:
Servomechanism Transient Performance from Decibel-Log Frequency Plots, H. Harris, Jr., M. J. Kirby, E. F. von Arx, Sperry Gyroscope Company

Power Division

First Prize awarded to:
Corona Investigation on Extra-High-Voltage Lines—500-Kv Test Project of the American Gas and Electric Company, I. W. Gross, Otto Naef, American Gas and Electric Service Corporation; C. F. Wagner, R. L. Tremaine, Westinghouse Electric Corporation

Second Prize awarded to:
A Study of Directional Element Connection for Phase Relays, W. K. Sonnemann, Westinghouse Electric Corporation

Science and Electronics Division

First Prize awarded to:
On the Mechanics of Magnetic Amplifier Operation, R. A. Ramey, Naval Research Laboratory

Second Prize awarded to:
Electrostatic Precipitation of High-Resistivity Dust, G. W. Penney, Carnegie Institute of Technology

STUDENT PAPERS

The Committee on Award of Institute Prizes has announced the award of the Best Student Paper Prizes for papers presented during the period August 1, 1950, to July 31, 1951. The committee reviewed all of the papers submitted for this prize, five reviews having been secured for each of the six best papers.

The papers selected for the awards are as follows:

Best Student Paper Prize

Prize awarded to:
The Application of Electrets to Instrumentation, Russell E. Peterson, University of Utah

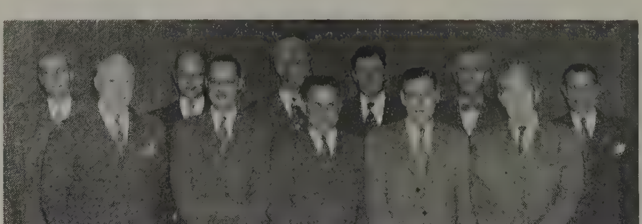
Second Prize Student Paper

Prize awarded to:
Application of CSPB Transformers in Secondary Banks, Samuel Corbin, Harold R. Moore, Mississippi State College

South West District Meeting Committee Chairmen Announced

The South West District Meeting will be held in St. Louis, Mo., on April 15–17, 1952. The Committee Chairmen for this meeting are: I. T. Monseth, *General Chairman;* R. C. Horn, *Vice-Chairman;* R. W. Schoetker, *Secretary-Treasurer;* H. R. Fritz, *District Vice-President;* R. G. Meyerand, *District Secretary;* R. N. Slinger, *Chairman, St. Louis Section;* C. B. Fall, *Finance;* H. M. Duphorne, *Hotels;* J. S. Malsbary, *Meetings and Papers;* O. L. Luft, *Registration;* S. C. Sachs, *Publicity;* E. G. McLagen, *Transportation and Trips;* R. J. W. Koopman, *Student Activities;* E. S. Rehagen, *Hospitality;* and Mrs. G. S. Whitlow, *Ladies'*.

The Executive Committee, consisting of the Chairmen of the various committees, has been meeting monthly since the spring of



Committee Chairmen for the South West District Meeting to be held April 15–17 in St. Louis, Mo., include, front row, left to right, R. J. W. Koopman, R. W. Schoetker, S. C. Sachs, I. T. Monseth, and R. C. Hase; back row, left to right, D. G. McLagen, O. L. Luft, R. C. Horn, J. S. Malsbary, H. R. Fritz, and E. S. Rehagen

Future AIEE Meetings

Joint AIEE-IRE-AEC-NBS Scintillation Counter Symposium
Bureau of Standards, Washington, D. C.
January 29–30, 1952

AIEE Conference on Induction and Dielectric Heating
Carter Hotel, Cleveland, Ohio
February 19–20, 1952

South West District Meeting (*page 190*)
Jefferson Hotel, St. Louis, Mo.
April 15–17, 1952
(*Final date for submitting papers—closed*)

Joint AIEE-AWS-IEESD Welding Conference (*page 191*)
Rackham Memorial Building, Detroit, Mich.
April 16–18, 1952

North Eastern District Meeting (*page 191*)
Arlington Hotel, Binghamton, N. Y.
April 30–May 2, 1952
(*Final date for submitting papers—January 31*)

Joint AIEE-IRE-RTMA Conference on Progress in Quality of Electronic Components
Washington, D. C.
May 5–7, 1952

AIEE Conference on Electronic Converter Applications and Tubes (*page 197*)
William Penn Hotel, Pittsburgh, Pa.
May 19–20, 1952

Summer General Meeting
Hotel Nicollet, Minneapolis, Minn.
June 23–27, 1952
(*Final date for submitting papers—March 25*)

Pacific General Meeting
Phoenix, Ariz.
August 19–22, 1952
(*Final date for submitting papers—May 21*)

AIEE Participation in Centennial of Engineering
Congress Hotel, Chicago, Ill.
September 10–12, 1952

Fall General Meeting
New Orleans, La.
October 13–17, 1952
(*Final date for submitting papers—June 13*)

Middle Eastern District Meeting
Commodore Perry Hotel, Toledo, Ohio
October 28–30, 1952
(*Final date for submitting papers—July 30*)

At the District 4 Executive Committee Meeting held in Birmingham, Ala., November 26, 90 per cent of the membership was present. A report was given by each section regarding such activities as technical meetings, open meetings, and meetings with state engineering societies and other professional engineering groups

1951 so that those attending the District Meeting are assured a well-rounded and interesting program.

AIEE Welding Conference to Be Held in Detroit April 16–18

The Third Annual Welding Conference has been scheduled for April 16, 17, and 18, 1952, at the Rackham Memorial Building, Detroit, Mich. A full program of papers and exhibits, together with a plant trip, is being arranged jointly by the AIEE, the Detroit section of the American Welding Society (AWS), and the Industrial Electrical Engineers Society of Detroit (IEESD).

C. M. Clark of the Duquesne Light Company is the chairman of the 1952 meeting. His executive committee consists of E. J. Limpel, *Papers;* C. M. Rhoades, Jr., *Publication;* J. S. Francis, Stanley H. Brams, *Publicity;* Dr. A. DiGiulio, *Demonstrations;* G. W. Garman, *Conference Treasurer;* S. W. Luther, *Local Chairman;* J. F. Deffenbaugh, *Secretary;* Keith Sheren, *AWS Representative;* and V. H. Chisholm, *IEESD Representative.*

North Eastern District Meeting to Be Held in Binghamton, N. Y.

The 1952 AIEE North Eastern District Meeting will be held at the Arlington Hotel, Binghamton, N. Y., from April 30-May 2. The Ithaca Section, which is the host, will celebrate its 50th anniversary. The triple cities of Binghamton, Johnson City, and Endicott are one of the fastest-growing industrial communities in the eastern part of the United States.

There will be five sessions of technical papers with three meetings for each session, covering all phases of electrical engineering with particular emphasis on power, transmission, and distribution.

On Thursday afternoon, May 1, there will be a Symposium on the Engineering Aspects of the Hydroelectric Development on the Niagara River at Niagara Falls and the St. Laurence River Development near Messina, N. Y. Prominent members of the AIEE in the United States and Canada will present papers on this subject.

Plans are under way for inspection trips to the International Business Machines Corporation factories and engineering building at Endicott; The Endicott Johnson Corporation shoe factories; Ansco Corporation, producer of photographic films and cameras; Goudey Electric Generating Station where the recent 75,000-kw reheat unit has just been put in service; Kroehler Manufacturing Company, one of the largest furniture manufacturers in the country; and Link Aviation Corporation, manufacturers of Link Trainers for the Army and Navy.

Inspection trips and entertainment have been provided for the ladies.

A stag smoker and banquet, honoring the 50th anniversary of the Ithaca Section, has been planned.

W. W. Perry of the Binghamton Subsection of the Ithaca Section is General Chairman of this meeting, and Professor M. S. McIlroy of Cornell University is Chairman of the Technical Papers Committee.

Four Sessions Planned for Electronic Converter Conference

The purpose of the AIEE Conference on Electronic Converter Applications and Tubes is to provide an opportunity to discuss the application of large pool tubes and equivalent devices to rectifiers for electrochemical, transportation, mining, and general industrial service. This conference will be held May 19 and 20, 1952, at the William Penn Hotel in Pittsburgh, Pa.

The papers and discussions are intended to treat those aspects of the subject of greatest interest to persons engaged in applying and operating power rectifier equipment. It is planned to review current operating problems, determine users' needs, and define application trends in the power rectifier field.

Four sessions will be held during the meeting. Arrangements are being made for inspection trips to local plants and installations of special interest.

District 4 Executive Committee Holds Meeting in Birmingham

The Executive Committee of District 4 met in Birmingham, Ala., on Monday, November 26. Ninety per cent of the membership was present. Each section reported on its activities.

E. S. Lammers, Jr., Vice-President of the District, discussed the working of AIEE and said that the life of AIEE is in the sections. The engineering profession is a ministry to the public, he stated, and its standing depends upon how we, as engineers, view this mission.

C. P. Knost, representing the Sections Committee, spoke on how to form sections, obtain speakers, and promote and set up subsections. Technical programs and vocational guidance are a good way of broadening section activities.

E. R. Colbourn, Vice-Chairman of the Membership Committee, reviewed the new membership qualifications, and spoke of the part AIEE is playing in unification and of its participation in Engineers Joint Council and Engineers' Council for Professional Development. A detailed discussion indicated a need for following all electrical engineering graduates from school into industry so that the sections could approach the graduates regarding membership in the Institute.

D. H. Vliet, Chairman of the Committee on Student Activities, reported that each student branch may submit to the judging

committee two papers in competition for the district prize. Tulane University in New Orleans, La., will be host to the Student Conference on April 17–19, 1952.

W. J. Seeley, retiring Vice-President of the District, outlined some of the recent activities of the Institute of national scope, noting particularly the division of publications by interests and the developments on unification of the engineering profession. He was elected to serve on the Nominating Committee for next year.

The next Executive Committee Meeting was scheduled for one day during the period of October 13–17, 1952, in New Orleans, La.

At the Scranton Division meeting were, front row, left to right, Mr. Brandon, A. W. Plonsky, manager, Scranton Division, Mr. Weisberger; back row, left to right, Edward Paul, publicity committee, A. L. Price, prize committee chairman, C. H. Sprague, past chairman, W.C Seymour, secretary-treasurer, J. H. Black, vice-chairman

AIEE Nominating Committee Meets in New York City

The Nominating Committee of the AIEE met at the Hotel Statler, New York City, on January 23, 1952, during the Winter General Meeting of the Institute to nominate candidates for AIEE offices to be voted on by the membership in the spring of 1952. Members of the committee are as follows:

Representing the Board of Directors:

W. J. Barrett, New Jersey Bell Telephone Company, Newark, N. J.

F. R. Benedict, Westinghouse Electric Corporation, Pittsburgh, Pa.

R. F. Danner, Oklahoma Gas and Electric Company, Oklahoma City, Okla.

J. R. North, Commonwealth Services, Inc., Jackson, Mich.

J. C. Strasbourger, Cleveland Electric Illuminating Company, Cleveland, Ohio

Representing the ten geographical Districts:

1. W. E. Birchard, General Electric Company, Pittsfield, Mass.
2. H. A. Dambly, Philadelphia Electric Company, Philadelphia, Pa.
3. J. P. Neubauer, Consolidated Edison Company of New York, Inc., New York, N. Y.
4. W. J. Seeley, Duke University, Durham, N. C.
5. J. C. Woods, Commonwealth Edison Company, Chicago, Ill.
6. M. L. Burgess, Westinghouse Electric Corporation, Omaha, Nebr.
7. S. M. Sharp, Southwestern Gas and Electric Company, Shreveport, La.
8. Carl A. Poppino, General Electric Company, Phoenix, Ariz.
9. Glenn Bates, Westinghouse Electric Corporation, Seattle, Wash.
10. C. R. Thornton, Canadian Line Materials, Ltd., Ottawa, Ontario, Canada

Alternates for Board representatives:

H. R. Fritz, Southwestern Bell Telephone Company, St. Louis, Mo.

J. A. McDonald, General Electric Company, Salt Lake City, Utah

Alternates for District representatives:

1. J. G. Tarboux, Cornell University, Ithaca, N. Y.

6. E. J. Ballard, University of Nebraska, Lincoln, Nebr.

7. H. O. Hodson, Southwestern Public Service Company, Amarillo, Tex.

Scranton Division Holds Dinner Meeting December 14

The Scranton Division of the AIEE Lehigh Valley (Pa.) Section held a dinner meeting in the Chamber of Commerce Building on December 14. Merwin Brandon, Vice-President of Underwriters' Laboratories, Inc., spoke on "What Does the Underwriters' Laboratories Label Mean?" Harold Weisberger, a senior physics major student at the University of Scranton, read a paper on "Electronic Instrumentation for Nuclear Energy Measurements."

Corpus Christi Raised to Full Section Status December 10

The Corpus Christi Section was inaugurated December 10, and in celebration a dinner-dance was held on that date. The organization of a Corpus Christi Section from the Corpus Christi Subsection of the South Texas Section was authorized by the AIEE Board of Directors on October 25, 1951.

Over 100 members and guests attended the affair, which was held at the Nueces Hotel in Corpus Christi, Tex. Thomas E. Duce, Chairman of the new Section, presided over the business part of the meeting. He introduced some past chairmen of the former Subsection, as well as representatives of the South Texas Section, including R. R. Krezdorn, its Chairman.

Elgin B. Robertson, a Director of the AIEE, was the principal speaker of the evening. He gave an interesting talk on Institute affairs, and made suggestions as to how the Section can be of national service in building up the prestige of the engineer, interesting young men in an engineering career, and working toward unity in the engineering profession.

Attending the dinner-dance celebrating the inauguration of the Corpus Christi Section were, left to right, R. R. Krezdorn, Jack Watts, Vice-Chairman of the Corpus Christi Section, Mr. Robertson, guest speaker, T. E. Duce, and J. R. Dickey, Secretary of the Section

De Luccia Speaks at Richland Section Dinner Meeting

E. Robert de Luccia, Vice-President and Manager and chief engineer of the Lewis River Development (Yale Project), described some features of the Yale Hydroelectric Development currently being constructed by the Pacific Power and Light Company on the Lewis River in southwest Washington at a meeting of the AIEE Richland Section. The dinner meeting was held at the Grand Hotel in Walla Walla, Wash., on December 17, and was attended by 42 members.

Mr. de Luccia illustrated his talk with slides, after which a sound color movie depicting the construction problems and solutions to date was shown.

Student Branch Meeting. A group of about 250 students from ten colleges in District 3 were guests of the New York Section at a meeting held at the Consolidated Edison Auditorium on December 7. C. S. Purnell, Vice-President for District 3, and J. P. Neubauer, Chairman of the New York Section, greeted the students, after which Mr. William Keister, a member of the technical staff of the Bell Telephone Laboratories, described, with his unique demonstration equipment, some of the interesting things that relays can be made to do in computers and in automatic switching systems when the logic of relay circuits is understood and applied. The talk was followed by a social period with refreshments.

J. R. North Is Guest Speaker at Northeastern Mich. Section

J. R. North, Chairman of the Great Lakes District, was guest speaker at the Vice

At a dinner meeting of the Northeastern Michigan Section J. R. North was guest speaker; he is shown in the front row (left) with A. E. Stevens, Chairman of the Section. In the back row, left to right, are J. E. Young, Secretary, Northeastern Michigan Section; G. W. Miller, Technical Program Chairman; A. P. Fugill, Secretary, Michigan Section; and N. E. Hehner, Vice-Chairman

President's Night dinner meeting of the Northeastern Michigan Section held at Owosso, Mich., on December 12. In his talk on "Engineering Opportunities," Mr. North outlined the typical methods used by industry and business in obtaining maximum benefits from and for engineers. He also stated that the general public should be more fully informed of the value of engineers and engineering to society.

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Communication Division

Committee on Communication Switching Systems (*John Meszar, Chairman; A. E. Frost, Vice-Chairman; William Keister, Secretary*). The committee has met unavoidable difficulties so far in presenting the design and engineering aspects of switching for nation-wide dialing. However, this subject is of such importance and interest that the committee will continue its efforts to present a symposium on it at the earliest possible opportunity.

General Applications Division

Committee on Land Transportation (*L. W. Birch, Chairman; S. R. Negley, Vice-Chairman; G. M. Woods, Secretary*). Electrification of railroads is of major importance to European operators. At the recent Annecy Conference of the French National Railways over 100 papers on electric traction were presented before a group of 300 engineers. Included in this group and representing the AIEE were two members of the committee, H. F. Brown and John C. Aydelott, both past chairmen. During the Conference an afternoon was devoted to an inspection of the Aix-les-Baines—La-Roche-sur-Faron line which has been experimentally electrified at 50 cycles with a 20-kv catenary system. Locomotives with 50-cycle motors and also rectifier locomotives were exhibited.

Both Mr. Aydelott and Mr. Brown presented papers covering the Annecy Conference at the Winter General Meeting. These papers, together with two excellent papers on the two new Pennsylvania electric locomotives, are indicative of renewed interest in the committee's electrification activities.

Power Division

Committee on Insulated Conductors (*C. T. Hatcher, Chairman; R. J. Wiseman, Vice-Chairman; M. H. McGrath, Secretary*). The committee continues to be active in the many varied subjects pertaining to insulated cables which come under its jurisdiction. Member interest has been high since the organization of the committee in 1947 as evidenced by the attendance of approximately 50 members and special members at each of its two annual meetings.

A full-day symposium on polyethylene was held at the 1951 Fall General Meeting in Cleveland. The meeting was very well attended and the demand for copies of the papers has been such that a request is to be made to have the papers printed in the form of a special AIEE publication. If approval is obtained, these papers will be available for purchase through AIEE Headquarters.

The Cable Supply Systems Subcommittee is working on preparing a group of papers on the Fundamental Requirements for the Application of Nonleaded Cables on Secondary Distribution Systems. When this work is completed, it is expected that a symposium will be held at one of the general meetings.

The use of aluminum for insulated conductors is being given considerable attention at the present time. To present the complete story on this problem the Cable Supply Systems, Utilization Wiring Systems, and Accessories Subcommittees have been requested to prepare plans for a symposium on this subject for the 1952 Fall General Meeting.

Committee on Rotating Machinery (*C. G. Veinott, Chairman; E. I. Pollard, Vice-Chairman; L. W. Buchanan, Secretary*). The Test Code for Polyphase Induction Machines, AIEE Standard *number 500*, has been revised and is now ready for ballot. The Code as revised has been co-ordinated with the revision of American Standards Association *number C-50* which is now in process.

The Insulation Subcommittee has formed two working groups. One of these will engage in a long-term study to evaluate insulation systems for rotating machines, including those recently developed. The groundwork on this project will consist of accumulating data on properties of materials such as aging in atmospheres other than air, voltage endurance, effects of moisture, abrasion, and vibration. It is recognized that the present classification of insulating materials as defined in AIEE Standard *number 1* is much too broad, particularly for new materials now available, and it is hoped that these data will lead to new definitions of insulation classes and a new test code for insulating materials. The other working group will prepare a comprehensive guide for the preventive maintenance, inspection, and testing of large rotating machinery insulation.

Joint Subcommittee on Carbon Brushes (*T. M. Linville, Chairman*). Makers and users of carbon brushes are interested in proposed standard apparatus and procedures for measuring the physical properties of brush materials and the rate of wear, losses due to friction and electrical resistance, and commutation ability. These procedures were given in a technical paper, "Proposed Test Code for Carbon Brushes," prepared by the subcommittee and presented at the AIEE Winter General Meeting. Special interest was shown in a procedure for measuring rate of wear under simulated high altitude conditions. For reliable test results the subcommittee chose to use for this test a sealed enclosure through which carefully dried air was drawn at room temperature at low pressure. Interest was focused also on the procedure for measuring commutation ability. This procedure determines the ability of the brush material to reverse the flow of current in a reactive coil without sparking or burning. Several companies are planning to try this test procedure extensively. The subcommittee believes that the proposed Code will assist research, development, and use of carbon brushes leading to improvements. New knowledge resulting from research and development offers the possibility of several technical papers for future AIEE meetings.

Science and Electronics Divisio

Committee on Metallic Rectifiers (*W. F. Bonner, Chairman; Geln Ramsey, Vice-Chairman; E. A. Harty, Secretary*). The committee had one session and two committee meetings during 1951. The session was held during

the Summer General Meeting. Six papers were presented which covered both metallic rectifiers and metallic rectifier equipment. Committee meetings were held on January 25, 1951, in New York City and June 27, 1951, in Toronto. During these meetings 15 definitions were approved for inclusion in the Standards. It was moved to turn over the sixth edition of the Standards, prepared by the committee, to AIEE to start the routine necessary to obtain American Standards Association approval.

Work has been done on the Bibliography on Metallic Rectifiers and a revised edition is expected to be available during this year.

A report was prepared by the Technical Subcommittee and presented to the committee on "Condenser Loading of Selenium Rectifiers and its Effect on Ratings."

A session is scheduled during the 1952 Winter General Meeting in New York City.

Committee on Nucleonics (*W. F. Davidson, Chairman; G. W. Dunlap, Vice-Chairman; W. E. Barbour, Secretary*). The interests of the committee may be divided roughly into: basic nuclear processes; instrumentation; industrial applications with particular reference to electric power.

Although there is intense activity in fundamental investigations in the field of nucleonics, most of this falls outside the interest of electrical engineers and it is reported in the publications of the American Institute of Physics and related organizations.

Instruments and measuring techniques needed in nuclear investigations almost without exception use electronic devices of one sort or another and it has seemed more appropriate that those of interest to electrical engineers should be handled by the Committee on Electronics or the Committee on Instruments and Measurements through the joint committee.

The use of nuclear fuels for generation of electric power is still an accomplishment for the indefinite future. However, partly as an outgrowth of the report on co-operation between the electric power industry and Atomic Energy Commission by the Adhoc Advisory Committee (*EE, Sep '51, pp 763–68*), studies are now under way by four teams of engineers recruited in part from five electrical utility companies to determine whether the time has arrived when nuclear reactors constructed primarily to produce fissionable materials mainly for the national defense program may be modified so as to produce power on a scale and at a cost which would make it commercially attractive. When and as the reports of these studies become available, the committee will bring them to the attention of the membership.

Joint Subcommittee on Nucleonics Instruments (*G. A. Morton, Chairman; P. W. Davison, Acting Secretary*). The subcommittee sponsored a technical session at the Winter General Meeting. Four papers relating to various phases of nuclear instrumentation were presented.

The class of radiation detectors known as scintillation counters is one of the most important types of instrument for nuclear research. As such, they are of considerable interest to the subcommittee, and it was one of the sponsors of the Scintillation Counter Symposium.

The subcommittee is planning to draw up a set of definitions and test procedure for the scintillation counter, paralleling the set covering radiation detector tubes prepared by the Institute of Radio Engineers Committee on Electron Tubes. This work is just being started.

The group also has given some assistance in the Civil Defense Program.

AIEE PERSONALITIES.....

R. T. Henry (A '24, F '33), chief electrical engineer, Niagara Mohawk Power Corporation, Buffalo, N. Y., has retired after 40 years' service. Mr. Henry was born on November 17, 1889, in Stronghurst, Ill., and attended the University of Michigan. In 1908 he became associated with the General Electric Company and subsequently served with Niagara Falls (N. Y.) Hydraulic Power and Manufacturing Company, Hooker Electrochemical Company, Niagara, N. Y., Edison Illuminating Company, Detroit, Mich., and the Niagara (N. Y.) Electric Corporation. From 1918 to 1929 he was assistant electrical engineer with the Niagara Falls Power Company, and in the latter year became electrical engineer in charge of design, Buffalo, Niagara and Eastern Power Corporation, Buffalo, N. Y. He was appointed chief electrical engineer of the company in 1945. He is a member of the National Electric Light Association. Mr. Henry has been an active member of the Institute, having served as Vice-President of the North Eastern District (number 1) from 1944–46, Director (1946–50), and on the following AIEE committees: Protective Devices (1931–34, Chairman 1932–34, 1939–45); Technical Program (1932–34); Standards (1936–52, Chairman 1940–42); Board of Directors (1944–50); Planning and Co-ordination (1940–42); Production and Application of Light (1944–45); Charles LeGeyt Fortescue Fellowship (1944–47, Chairman 1945–47); Executive (1945–50); Marine Transportation (1946–47); Edison Medal (1946–50); and Finance (1948–50).

R. T. Henry

C. W. Mier (A '25, F '39), chief engineer, Southwestern Bell Telephone Company, Dallas, Tex., has retired after 40 years of service. He was born on September 21, 1886, in St. Louis, Mo., and was graduated from Washington University in 1909 with a bachelor of science degree in electrical engineering. He has been associated with the Southwestern Bell Telephone Company continuously since 1910 and has held various positions in the company including traffic engineer, transmission engineer, general transmission and protection engineer, and area engineer. Mr. Mier has been an active member of the Institute, having served as Director (1943–47), and on the Communications (1943–47) and Sections (1947–48) Committees.

C. W. Mier

W. A. Morgan (A '34, F '51), Head, power system technical section, electrical engineering division, United States Bureau of Reclamation, Denver, Colo., is now on the consulting engineering staff of Ebasco Services, Inc., New York, N. Y. Prior to his 10 years' service with the Bureau of Reclamation, Mr. Morgan spent 8½ years with the Metropolitan Water District of Southern Calif. He is a member of Tau Beta Pi and has served actively on the following AIEE committees: Relays (1948–51); System Engineering (1951–52); and Transmission and Distribution (1951).

J. F. Lincoln (A '08, F '39, Member for Life), President, Lincoln Electric Company, Cleveland, Ohio, has been elected President of the National Electrical Manufacturers Association. A graduate of Ohio State University, Mr. Lincoln was sales engineer for the Lincoln Electric Company from 1907 to 1911, became general manager in 1914, and President in 1929. He is an active member of the Institute, having served on the following AIEE committees: Industrial and Domestic Power (1920–21); Lighting and Illumination (1920–21); and Mines (1920–21).

L. C. Marshall (A '38, M '47), professor of electrical engineering, University of California, Berkeley, Calif., has been appointed Director of the Physical Testing and Research Laboratory, Link-Belt Company, Indianapolis, Ind. Dr. Marshall was graduated from Park College and received the degree of doctor of philosophy from the University of California. He joined the

staff of the University of California in 1937. He is a member of Sigma Xi, Eta Kappa Nu, the Institute of Radio Engineers, and the American Physical Society. He is currently serving the Institute on the Nucleonics Committee.

J. L. Fuller (A '37, M '45), manager, Large Motor Engineering Department, Reliance Electric and Engineering Company, Cleveland, Ohio, has been appointed to the position of manager of research and technical services. He has been associated with the company since 1936, following graduation from Case Institute of Technology with a bachelor of science degree in electrical engineering. Mr. Fuller is a member of Tau Beta Pi, Eta Kappa Nu, and Sigma Xi. He has served on the AIEE Instruments and Measurements Committee (1943–48), and Rotating Machinery Committee (1947–52).

J. C. Peters (A '26), associate director of research, Leeds and Northrup Company, Philadelphia, Pa., received an award from the Department of the Army for his contribution to the World War II effort in industrial intelligence. Mr. Peters investigated the German instrument industry. He is a member of The American Society of Mechanical Engineers, the American Physical Society, the American Association for the Advancement of Science, and the Instruments Society of America. He holds patents on apparatus for several different industrial processes.

C. E. Scholz (M '26), Vice-President and chief engineer, Mackay Radio and Telegraph Company, New York, N. Y., has been elected Vice-President and chief engineer of the American Cable and Radio Corporation. Mr. Scholz has been associated with the International Telephone and Telegraph System and its affiliated companies since 1917, when he joined the Federal Telegraph Company as an engineer. He is a member of the Institute of Radio Engineers.

Philip Ryan (A '22, M '30), Vice-President and chief engineer, Cutler-Hammer, Inc., Milwaukee, Wis., has been appointed Executive Vice-President. Mr. Ryan began his career in the company in 1920.

M. H. Kight (A '37, M '49), assistant head, electrical division, United States Bureau of Reclamation, Denver, Colo., has been appointed head of the Bureau's electrical branch of the division of design and construction. He joined the Bureau of Reclamation in 1923, and has been in the Denver office since 1924.

Kern Dodge (A '02, M '12, Member for Life), consulting engineer, Philadelphia, Pa., has been cited for civic and educational activities by Drexel Institute. He is a member of The American Society of Mechanical Engineers.

W. H. Biester, Jr. (A '41, M '51), President, Electro Construction Company, Philadelphia, Pa., has been cited for educational interests and activities, and for professional accomplishments in the field of electrical engineering by Drexel Institute. He is a member of the American Standards Association.

F. L. Snyder (M '46, F '51), engineering manager, transformer division, Westinghouse Electric Corporation, Sharon, Pa., has been named manager of the aviation gas turbine division. Mr. Snyder has served the Institute on the Transformers Committee since 1946.

Millard Westrate (A '37, M '43), superintendent of Public Works, Holland, Mich., has been put in charge of bulk power system engineering, Commonwealth Services, Inc., Jackson, Mich.

J. S. Askey (A '39, M '45), manufacturing superintendent, transportation and generator division, Westinghouse Electric Corporation, East Pittsburgh, Pa., has joined the staff of the Elliott Company, Ridgway Division, Ridgway, Pa., as assistant works manager.

E. A. Rothfus (A '35, M '45), Commonwealth Services, Inc., Jackson, Mich., has been placed in charge of distribution system engineering for the company. He formerly was associated with the Westinghouse Electric Corporation.

E. G. Holzmann (A '50), research assistant, Massachusetts Institute of Technology, Cambridge, Mass., has joined the staff of the Shell Development Company, Emeryville, Calif.

OBITUARY • • • • • •

James Sherman Gault (A '24, M '30, F '46), professor of electrical engineering, University of Michigan, Ann Arbor, Mich., died on November 16, 1951. He was born on June 23, 1899, in Detroit, Mich., and was graduated from the University of Michigan with a bachelor of science degree in electric engineering in 1921 and a master of science degree in electrical engineering in 1924. For one year after his graduation Mr. Gault was associated with the General Electric Company, then in 1922 he joined the faculty of the University of Michigan as an instructor in electrical engineering. He was made an assistant professor in 1930, an associate professor in 1941, and in 1946 he became a full professor. He was a member of Sigma Xi. An active member of the Institute, he served on the following AIEE committees: Industrial Power Systems (1943–52); Rotating Machinery (1948–52, Chairman 1949–51); Technical Program (1949–50); Standards (1949–50); Industry Co-ordinating (1949–52); Award of Institute Prizes (1951–52).

Montgomery Waddell (A '88, M '88, Member for Life), consulting engineer, New Canaan, Conn., died on December 21, 1951. He was born in 1862 at Port Hope, Ontario, Canada, and in 1884 was graduated from Rensselaer Polytechnic Institute. He was a member of the American Institute of Civil Engineers.

Leon R. Ludwig (A '28, M '41), director of engineering and research, Atomic Power Division, Westinghouse Electric Corporation, Pittsburgh, Pa., died on November 4, 1951. He was born on July 12, 1904, in Kansas City, Mo., and was graduated in 1925 from the University of Illinois with a bachelor of science degree. He had been associated with Westinghouse since his graduation and had held various positions in the company. He served the AIEE on the Protective Devices Committee (1938–44).

Olen G. Coffman (A '47), electrical engineer, Robbins and Myers, Inc., Springfield, Ohio, died on December 11, 1951. He was born in Laurel, Ind., on July 30, 1899, and was graduated from Ohio Northern University in 1923 with a bachelor of science degree in electrical engineering. Mr. Coffman had been a motor designer for Robbins and Myers, Inc., for most of his professional career and had been in charge of the induction motor design section.

MEMBERSHIP • • • •

Recommended for Transfer

The Board of Examiners at its meeting of December 20, 1951, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute. A statement of valid reasons for such objections, signed by a member, must be furnished and will be treated as confidential.

To Grade of Member

Burke, D. C., application engr., General Electric Co., Portland, Oreg.
Chase, M., asst. chief, power div., Rural Electrification Administration, Washington, D. C.
Das Gupta, M. S., resident engr., Jharsuguda Electric Supply Co., Ltd., Jharsuguda, India
Graves, W. H., director, municipal utility, electric dept., City of Martinsville, Va.
Hughes, A. V., director of engineering, Kuhlman Electric Co., Bay City, Mich.
Jaeschke, R. L., research engr., Dynamatic Corp., Kenosha, Wis.
Jordan, J. P., section head, electronics laboratory, General Electric Co., Syracuse, N. Y.
Kahal, R., assoc. prof. of elec. engg., Washington University, St. Louis, Mo.
Lusher, M. H., superintendent of power, Public Service Co. of Northern Illinois, Evanston, Ill.
Malick, F. S., engineer, Westinghouse Electric Corp., Pittsburgh, Pa.
Nickerson, O., office engr., General Electric Co., Chicago, Ill.
Potter, L. A., distribution engr., Salt River Power District, Phoenix, Ariz.
Puls, A. E., electrical engr., Sverdrup & Parcel, Inc., St. Louis, Mo.
Ryan, R. E., electrical engr., power div., Rural Electrification Administration, Washington, D. C.
Sackett, W. T., Jr., principal electrical engr., Battelle Memorial Institute, Columbus, Ohio
Tones, T. E., electrical engr., Detroit diesel engine div., General Motors Corp., Detroit, Mich.
Travis, J. W., chief engr., Southern Bell Tel. & Tel. Co., Birmingham, Ala.

17 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should supply a signed statement to the Secretary before February 25, 1952, or April 25, 1952, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Dillon, W. K., Landis & Gyr A. G., Zug, Switzerland
Suez, R. K., Anglo-French Engg. & Equipment, Div. of Anglo-French & Bendixsen, Ltd., Singapore, China
Trubshaw, T. H. A., Townsville Regional Electricity Board, Townsville, Qld., Australia

3 to grade of Member

Antenna Range Uses Model Techniques for Radiation Pattern Measurements

The National Bureau of Standards (NBS) recently completed a new model antenna range to facilitate the measurement of antenna radiation patterns in the vertical plane. It is composed of an inverted V-type structure which supports a test or target transmitter more than 50 feet above a ground plane, in the center of which is placed the model antenna to be tested. The model techniques employed in this type of installation are being applied to an NBS investigation of the behavior of high-frequency antenna systems used in ionosphere-sounding equipment.

The NBS antenna investigations are concerned particularly with the high-frequency band from 3 to 30 megacycles, in which the major portion of long-distance communication is carried on. At these frequencies the wavelength varies between 300 and 30 feet; consequently measurements of full-sized antennas would require a site several thousand feet long. This presents a problem when merely ground plane radiation patterns are desired; but, when the pattern in a vertical plane is required, the problem becomes even more complex.

The model techniques employed in NBS antenna studies are similar in many ways to those used in the investigation of mechanical, hydraulic, and aerodynamic structures. The principle is known as electrodynamic similitude. As applied to an antenna, an equivalent performance is obtained from a model $1/n$th as large as the prototype antenna if its operating frequency is made n times the prototype frequency. As the model frequency is increased, the free-space wavelength is decreased proportionately, and the distance between the transmitting and the receiving antennas then can be reduced by the same scaling factor, n. Thus it becomes possible, by using a sufficiently large scaling factor, to mount a target transmitter on a rigid structure, to move it over and about the model antenna under test, and to obtain radiation patterns substantially the same as the true long-distance radiation patterns of a full-scale antenna.

The measurement of antenna radiation patterns is very complex, especially when the antenna system is intended for long-distance operation. Several restrictive problems must be overcome before actual transmitting conditions can be simulated. For example, the wavefront intercepted by the antenna to be tested must be essentially plane, and the phase relationship of the voltages induced in it must appear as though the wave had originated at a distance large compared to the size of the antenna. Also, a separation of at least several wavelengths must exist between the target transmitter and the test antenna in order to minimize the surface wave component of the radiated electromagnetic field.

In recognition of these restrictions, a scaling factor of $60 (n=60)$ is employed in many of the applications. Thus, a prototype frequency between 1 and 25 megacycles is represented by model-transmitter frequencies between 60 and 1,500 megacycles. At these frequencies, it is comparatively easy to arrange a model transmitting-receiving system so that it satisfies both of the previously mentioned restrictive problems.

In addition to dividing the physical dimensions of the model by the scaling factor, n, and multiplying the frequency by the same factor, it is necessary to multiply the conductivity of the antenna and the ground by n. One type of ground which does not require a scaling factor is a perfectly reflecting surface. Communication sites located on salt marshes and over sea water practically have this type of ground. For the purpose of the model range, the problem of scaling the ground was resolved, therefore, by simulating a perfect ground by placing a ground covering consisting of a metal hardware cloth.

The target transmitter is supported by two open-truss beams, each 60 feet in length, fastened together at one end to form a 60-degree angle. The other two ends of the beams are mounted to two horizontal colinear axes located just high enough above the ground to permit a 180-degree movement of the structure. The structure is counterweighted so that it requires very little power to move it through its path. The target transmitter is fitted into the vertex of the inverted V, and the model antenna is located at the center of the ground plane.

The radio energy intercepted by the model antenna is rectified and the signal voltage is transmitted along underground cables to a recording pen attached to an automatic pattern plotter. Synchrogenerators, connected to the axis of the V-frame, transmit its position to the turntable of the pattern plotter. Thus an automatic record of the radiation pattern is plotted as a function of the angular displacement of the transmitter moving above the antenna.

A series of target transmitters which derive their operating power from small storage batteries within the unit are employed. This obviates the necessity of using connecting cables and wires which could reflect or otherwise disturb the radiated field. To prevent reflections that would be set up by a conducting material, the truss beams forming the V-frame are made of nonconducting hard plywood.

The picture on the left gives a full view of the new NBS model antenna range with the target transmitter raised to a 90-degree position. The inverted-V structure supports a self-contained target transmitter at the vertex and is designed to be moved in a 180-degree arc. The antenna to be tested is placed at the center of the oval-shaped ground plane. The middle picture gives a close-up of the test antenna which is a high-frequency model of one that normally is used at a much lower frequency. The voltage induced is rectified and transmitted to an automatic pattern-recorder by an underground cable system. The transmitter in the vertex, shown at the right, is a self-contained unit which derives its operating power from wet-cell batteries. The operating frequency of this unit is between 60 and 1,500 megacycles

New Copper Cladding Method to Help Relieve Metal Shortage

A new process whereby copper is bonded inseparably to steel was demonstrated recently in the metallurgical laboratory of the James H. Herron Company, Cleveland, Ohio. This process produces a bimetal in which the copper is bonded to the steel and may be the answer to the civilian need for the material of a thousand uses—copper.

This development is the result of research by the Automatic Gasflux Company and the Superior Flux and Manufacturing Company, Cleveland, Ohio. Ten years have been spent in developing a process for producing a bimetal which makes possible the production of sheets 80 per cent steel and 20 per cent copper. These sheets combine the corrosion resistance of copper with the strength of steel and can be deep drawn or otherwise deformed without danger of separation of the constituent metals. The process starts with the thick slabs of steel on which molten copper or copper alloy is cast. The bimetal slab then is rolled into commercial-sized sheets, plates, and strips. Any percentage of copper or brass to steel can be produced from 10 per cent up.

Many products can be made from this bimetal instead of from solid copper or brass without impairing their efficiency. In many cases the product would be improved by adding the strength of steel to the corrosion resistance of copper.

In casting molten copper on to steel in the early experiments, it soon was found that a flux had to be used to counteract the oxides which form when metal is heated. Heretofore, in the many experiments that were made over the years, such a flux was necessarily a solid: either a paste, a powder, or a liquid. It also was found that it was impossible to dispose completely of such a flux and its residues in the casting and that some of it was captured between the two metals, forming pockets and inclusions and resulting in unbonded areas.

It was not until about 12 years ago that Gasflux was introduced on the market. A highly volatile liquid flux, it is used in brazing and welding procedures.

This new method of cladding is an extension on a large scale of the brazing process which has been performed successfully on smaller pieces for many years, through the use of this vapor-phase Gasflux. Experimental work also was conducted for several years to determine the application of this process of cladding copper and its alloys to other metals, stainless steel for example.

It is claimed that the process is simple and economical since it uses steel in the form of slabs and copper in the form of ingots. It is adaptable for use in ordinary steel and brass rolling mills; no special expensive equipment is required.

The process has gone through the experimental and development stage and is now ready for commercial use. Bimetal slabs up to $3^1/_2$ inches thick, carrying approximately 20 per cent copper and 80 per cent steel, have been made and successfully hot-rolled into sheet bar and commercially sized sheet and strip by several steel companies. Their experience shows that bimetal slabs made according to this process can be processed and finished much the same as steel slabs. Sheets down to 16-gauge thickness and 30 inches wide were successfully hot-rolled and this metal then was cold-rolled down to 0.005 inch in thickness. In the finished sheets there was no separation of bond and the proportion of copper to steel was maintained throughout the rolling.

Future Meetings of Other Societies

American Society of Tool Engineers. 20th Annual Meeting. March 17–21, 1952, Conrad Hilton Hotel, Chicago, Ill.

Hydraulic Institute. January 30–February 1, 1952, Seaview Country Club, Absecon, N. J.

Institute of Aeronautical Sciences. 20th Annual Meeting. January 28–February 1, 1952, Astor Hotel, New York, N. Y.

Institute of Radio Engineers. Annual Convention. March 3–6, 1952, Waldorf-Astoria Hotel and Grand Central Palace, New York, N. Y.

Instrument Society of America. Power Plant Symposium held by New York Section. February 7–8, 1952, Hotel Statler, New York, N. Y.

National Association of Corrosion Engineers. Annual Conference. March 10–14, 1952, Buccaneer Hotel, Galveston, Tex.

National Electrical Manufacturers Association. March 10–13, 1952, Edgewater Beach Hotel, Chicago, Ill.

Pennsylvania Electric Association. Prime Movers and Electrical Equipment Committees. February 28–29, 1952, Benjamin Franklin Hotel, Philadelphia, Pa.

The Society of the Plastics Industry, Inc. Fifth National Plastics Exposition. March 11–14, 1952, Convention Hall, Philadelphia, Pa.

Protective Headgear Adds to Safety of Power Linemen

For better protection of line crews, the safety-conscious electric power industry is adopting protective headgear of the type commonly used on construction projects and throughout the mining, steel, petroleum, and shipbuilding industries.

Among the first in the power industry to join this move for greater protection of line crews is Consumers Power Company of Jackson, Mich. Company linemen now are using laminated plastic protective hats for pole-top, surface, and underground work.

The protective helmet is part of the company's recently revised safe practices for line crews, recommended by a special committee appointed to study ways and means of making work on energized equipment safer. The hat was selected for its high insulation properties to provide protection in case contact is made with high-voltage conductors, as well as for its exceptionally high mechanical strength for protection against falling objects. Linemen are exposed to many such hazards, and it has been reported that the safety helmets already have prevented injuries to linemen.

Although the use of safety hats to protect linemen from electric shock is comparatively new, the results obtained in less than a year have more than justified the program both from the standpoint of cost and in injuries prevented.

The hat is designed to withstand severe impact, and a webbing cradle is built in to distribute the force of an impact over a large area, thus offering additional protection to the wearer's head and neck. The smoothly rounded crown causes falling objects to glance off. The hats are light in weight and are adjusted easily to various head sizes. For winter wear, a quickly inserted warm cloth liner is provided.

The protective hat worn by this lineman is now standard equipment of the Consumers Power Company of Jackson, Mich. The hat, with high dielectric properties, protects against electric shock as well as against falling objects, such as insulators and tools. It is made of laminated plastic

Precise Camera Synchronization Improves Technical Movies

A new high-precision system for synchronized motion picture camera operation, providing five times closer time synchronization than has been possible heretofore, was announced recently by J. A. Maurer, Inc., Long Island City, N. Y.

The system achieves consistent and accurate simultaneous operation to close tolerance of two or more motion picture cameras. Maximum possible deviation of shutter position in this system, which utilizes circular rotating camera shutters, is less than 1 degree, which at 12 frames per second is equivalent to an accuracy of 23 microseconds. As frame frequency increases, the angular accuracy of synchronization remains essentially unchanged while the time accuracy increases.

For example, at 50 frames per second, the angular deviation is still approximately 1 degree and the time accuracy has increased to a maximum deviation of 35 microseconds. Due to the nature of the continuously rotat-

Television Honors Pioneer TV Scientist

Dr. E. F. W. Alexanderson (right), General Electric's television pioneer, photographed as he made his first appearance in the medium he helped develop. This picture was taken 25 years to the day after Dr. Alexanderson had announced that the transmission of moving pictures by radio was now possible. The venerable and still active scientist, holder of over 300 patents in the electronics and allied fields, was the guest of Fred Waring (left) on his Sunday night program, December 16th. In the background, offering an example of 25 years of General Electric television progress, can be seen the modern General Electric 24-inch console television receiver and the 3-inch octagonal receiver, one of Dr. Alexanderson's earliest experimental models

ing system, failures common to pulse-operated systems are eliminated.

The Servo-Sync Camera Drive system has been applied to a 35-millimeter motion picture camera of standard manufacture which uses interchangeable magazines having capacities of 400 and 1,000 feet of film. The system is not limited to one camera type but is applicable equally for use with a large number of motion picture, scientific, and ribbon-frame cameras, and motion picture and process projectors.

Among the scientific and engineering applications for which this system will be utilized are: data recording, flight testing, missile tracking, ordnance evaluation, and most applications where two or more sources of information must be recorded at essentially the same time.

There is no practical limit to the number of cameras that may be synchronized by this method. A possible use lies in 3-dimensional studies where two geometrically oriented cameras are required for simultaneous recording. The system also has application in professional and television motion picture production where extremely close time synchronization of a number of cameras, projectors, or sound recording apparatus is required.

Engineering Curricula and Programs Accredited by ECPD

The work of accrediting undergraduate engineering curricula and the programs of the technical institute type in the United States has been continued by the Educational Committee of the Engineers Council for Professional Development (ECPD). The work of accreditation has received wide acceptance by the schools, the profession, and the public.

As of October 20, 1951, ECPD had accredited 680 engineering curricula representing 148 different schools with accredited curricula. Some 62 programs of the technical institute type have been accredited in 22 technical institutes.

The complete list of accredited undergraduate engineering curricula by institutions and by curricula as well as the list of accredited programs of the technical institute type has been made available by ECPD in a pamphlet with statements on the bases of accrediting. This list may be purchased at a price of 25¢ each. Please address all orders to the Secretary of ECPD, 29 West 39th Street, New York 18, N. Y., and include remittance with order.

French to Study United States Electric Power Industry

The French electric power industry, attempting to cope with a steadily rising demand for electric power for defense, industrial, and consumer use in France and her overseas territories, has sent ten technologists and management representatives to make a 5-week study of the American industry under the Economic Co-operation Administration's productivity and technical assistance program.

The team's findings will be disseminated through a team report to the French electrical industry, and by films and lectures to workers and management in the industry.

The consumption of electricity in France, according to plans and forecasts, was expected to rise 15 to 20 per cent during 1951, and another 15 per cent during 1952. To help meet the increased demand, the nationalized French power industry is seeking to develop improved production techniques and distribution facilities.

The team's United States study is expected to make a major contribution toward strengthening the French economy by showing this industry how expenditures may be reduced in improving and modernizing existing plants and equipment, and by more efficiently organizing the transmission and distribution systems.

The French technicians will make a thorough study of American construction and operation of generation, transmission, and distribution systems. They also will study American methods of organization, personnel training, and worker attitudes. Their itinerary includes visits to modern electrical power installations and developments, and talks with labor and management officials.

Guide Issued by NSF for Applicants for Research Grants

The National Science Foundation (NSF) is authorized to support basic scientific research in the mathematical, physical, medical, biological, and engineering sciences by making grants for such research to education, industrial, governmental, or other institutions, or individuals. Ordinarily grants will be awarded to institutions for research by specified individuals.

In reviewing proposals the Foundation will emphasize the scientific merit of the suggested research, including the competence of the scientist under whom the study will be made.

The Foundation normally will provide sufficient funds in the grant for such items as the salaries of personnel, materials, equipment, necessary travel, publication, and other direct costs. In addition, the grant normally will be sufficient to cover indirect costs up to 15 per cent of the total direct costs covered by the grant.

Further information concerning this subject may be obtained from the National Science Foundation, 2144 California Street, N. W., Washington 25, D. C.

Automatic Tension Control Aids in Paper Production

Greater paper production because of fewer paper breaks and less down time has been accomplished through closer control of tension at the Spring Grove, Pa., plant of the P. H. Glatfelter Company.

The company, manufacturers of book, writing, bond, and specialty papers, is using a recent improvement in paper machine control, a General Electric paper tensiometer, to control paper tension automatically and continuously as the processing paper races between the calender rolls at hundreds of feet per minute.

Paper tension, difficult to control, previously has been controlled indirectly by automatic regulation of section motor speed or section motor current.

With the installation of the paper tensiometer as an automatic control, tension of moving sheet is held constant regardless of changes in any of the variables affecting tension, such as freeness, consistency, dryer temperature, moisture content, calender stack loading, or friction load variations.

The tensiometer utilizes only one very short roll and therefore does not complicate the paper threading machine.

In operation, the small, 4-inch roller on the tension head rides on top of the moving sheet of paper so that a slight hole is depressed into the sheet. Variations in the sheet tension change the air gap of a magnetic structure inside the device which emits an electric signal proportional to the paper's tension. This is transmitted through the power unit which contains the metering circuits, indicating instrument, and operator's controls.

Metals Exposed to Atomic Radiation Cut Electrolytically

Sectioning of metal bars by electrolytic methods to safeguard personnel against the hazard of machine cutting of metals exposed to high levels of atomic radiation has been accomplished at the Columbia University School of Engineering under a grant from the Atomic Energy Commission. This is believed to be the first successful electrolytic cutting of metal in the United States.

The method can be applied, when it is desirable, to cut metal bars without causing structural distortion on the cut surfaces. Steel bars 5/8 inch in diameter have been cut in about 24 hours by the new process, and the cut surfaces are comparable in flatness and smoothness to the results attained by moderately fine machining methods.

It is predicted that, with further development of the process, very smooth and polished surfaces can be obtained.

The process consists of making the specimen to be cut the anode in an electrolytic cell and using an appropriate electrolyte and cathode assembly. The flatness of the cut surface is produced by a novel design of cathode assembly which is the principal invention of the process.

The grant under which this research was carried out is one of a number awarded to the Columbia University School of Engineering by the Atomic Energy Commission.

New Marine Steering Aid Reduces Collision Chances

A new fail-safe ship steering servo system employing magnetic amplifiers permits tracking of steering wheel and rudder to an accuracy of 0.25 degree. The new marine steering aid was developed by the Bogue Electric Manufacturing Company, Paterson, N. J.

In all presently known types of steering servo systems, failure of the electric control cable which links the steering wheel with the steering engine has caused the rudder to swing hard to port or starboard. With the new steering servo the rudder stays in the position to which it was set at the instant of control-cable failure, thus keeping the ship on its course. This fail-safe feature was incorporated to reduce the possibility of collisions or running aground.

A precision potentiometer coupled to the steering wheel transmits electrical intelligence through an electric cable to the magnetic amplifier servo unit located near the steering engine. When the wheel is turned this electrical intelligence causes the servo unit to position the valve on the steering engine to the correct position, which, in turn, moves the rudder to keep it in synchronism with the steering wheel. The steering servo operates from the ship's electric power mains and consumes less power than a 100-watt light bulb. It is adaptable to ships of any tonnage and its use introduces no additional delay in the steering system.

Radio-Frequency Heating Hardens Shuttle Tips Faster

Radio-frequency induction heating is hardening several million textile shuttle tips per year at the Charles A. Richardson Company, West Mansfield, Mass. It is increasing production and decreasing rejects, floor space required, smoke, and fumes.

With radio-frequency heating it is possible to selective-harden the shuttle tips, 24 different sizes of them, at production rates of up to 3,000 per hour. Selective hardening, by means of exact and automatic process control, produces a high degree of hardness at the point where maximum wear occurs, and relative softness for toughness at the points of maximum stress.

The carburizing furnaces previously used required 200 square feet of floor space; the 20-kw radio-frequency generator and integral work-handling equipment designed by the Westinghouse Electric Corporation require less than 30 square feet. The equipment is fully automatic, and can be operated by unskilled labor.

The work-handling equipment is arranged for manual loading, with automatic position, hardening, and discharge. A process timer built into the machine controls the positioning, heating, and quenching cycles, and reduces rejects because of uniformity of heat treatment.

Report Shows Missouri River Basin Electric Power Potential

A long-range inventory of electric power development possibilities in the Missouri River Basin which is adequate to meet an anticipated 2,000,000-kw shortage in 1960 and a 7,900,000-kw shortage in 1970 is presented in a recently completed Bureau of Reclamation survey of the power resources, requirements, and supply in the Basin.

The report lists an additional 2,000,000 kw of hydroelectric capacity which may be available at 147 sites not yet authorized for development. This potential plus 2,600,000 kw from Federal plants now operating, under construction, or authorized would provide 4,600,000 kw of hydroelectric power from the Missouri River Basin system. The Bureau of Reclamation is charged with the responsibility of marketing all power generated at plants built by the Bureau and the Corps of Engineers as a part of the Federal water resources development program in the Missouri River Basin.

The report, based on a year-long field study, estimates the Basin's 1950 firm electric energy requirements at 4,568,000 kw of capacity, with 18,211,000 kilowatt-hours of production. In 1960, it will be 8,529,000 kw of capacity with 37,710,000 kilowatt-hours of production; in 1970, it will be 13,390,000 kw of capacity and 58,280,000 kilowatt-hours.

The Missouri River Basin, 1,300 miles long and 700 miles wide, contains a total of 529,000 square miles and includes all or part of 10 States—Nebraska, practically all of Montana and South Dakota, over half of Wyoming, North Dakota, and Missouri, the northeastern quarter of Colorado, the northern half of Kansas, and smaller areas of Iowa and Minnesota.

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

ASTM STANDARDS ON TEXTILE MATERIALS (with Related Information). Prepared by Committee *D-13* on Textile Materials, issued annually. American Society for Testing Materials, Philadelphia, Pa., 1951. 595 pages, illustrations, tables, diagrams, 9 by 6 inches, paper, $5.00. The following wide range of topics is covered by the 88 specifications, test methods, and tolerances presented: asbestos, bast and leaf fibers, cotton, glass textiles, rayon and silk, wool, pile fabrics, and felt; general fibers, fabrics, yarns, threads, and cordage; identification, qualitative and quantitative analysis; resistance to insect pests and microorganisms; testing machines. There are tests on snag resistance and stretch of hosiery and other specialized items. A group of useful tables is appended and an extensive glossary of textile terms is given including photographic illustrations of fabric defects.

BASIC ELECTROTECHNICS. By B. L. Goodlet. Edward Arnold and Company, London, England, 1951. 247 pages, charts, tables, diagrams, $8^3/_4$ by $5^1/_2$ inch, cloth. Available in the United States from Longmans, Green and Company, $4.00. This text is designed to provide the basic minimum of electromagnetic theory required to understand modern developments in electrical engineering. The area covered is indicated by the chapter headings: steady electric currents; electrostatic fields, condensers, and dielectrics; electrodynamics; calculation of magnetic fields; alternating currents; Maxwell's equations and electromagnetic waves. Some knowledge of physics and calculus is assumed.

BERECHNUNG MECHANISCHER SCHWINGUNGEN. By Fritz Söchting. Springer-Verlag, Wien, Austria, 1951. 325 pages, charts, tables, diagrams, $9^1/_4$ by $6^1/_4$ inches, cloth, $9.80. A brief section on fundamentals introduces this analytical treatment of mechanical vibrations. The two following sections deal respectively with conventional representations of single-mass and multiple-mass systems. The vibration of elastic bodies is discussed at considerable length in section IV, and the final section is devoted to actual machine elements, instrument parts, and such physical objects as propellers, ships, and so forth.

Library Services

ENGINEERING Societies Library books may be borrowed by mail by AIEE members for a small handling charge. The library also prepares bibliographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th St., New York 18, N. Y.

ELECTRICAL ENGINEERING ECONOMICS. Volume 2: Costs and Tariffs in Electricity Supply. By D. J. Bolton. Chapman and Hall, London, England, second revised edition, 1951. 307 pages, charts, tables, diagrams, $8^{3}/_{4}$ by $5^{1}/_{2}$ inches, cloth, Sh. .30/-. The aim of this work is to give to practising engineers and students a plain account of such elementary economics as most nearly concerns them, together with its application to certain engineering problems. Part I deals with the theory of price fixing; Part II, with cost details and load studies; Parts III and IV cover the actual retail tariffs, being descriptive and explanatory in character and dealing primarily with types rather than magnitudes. There is a section on the costs and tariffs aspect of power factor. The book is based essentially on British practice.

ELECTROLYTIC POLISHING AND BRIGHT PLATING OF METALS. By S. Wernick. Alvin Redman, Ltd., London, England, second edition, 1951. 243 pages, charts, tables, illustrations, $8^{3}/_{4}$ by $5^{1}/_{2}$ inches, cloth, 30s./-. This second edition is essentially a reprinting of the first edition issued in 1948, which was out of print. The book covers the electrolytic polishing of stainless steels, nickel, aluminum, carbon steels, copper and silver; bright nickel, zinc, cadmium, copper and silver plating; and the deposition of platinum, palladium, and rhodium. There is a bibliography of over 500 references.

ELEKTRISCHE MASCHINEN. Volume 1: Allgemeine Berechnungselemente, Die Gleichstrommaschinen. By Rudolf Richter. Verlag Birkhäuser, Basel, Switzerland, second edition, 1951. 630 pages, charts, tables, diagrams, illustrations, $9^{1}/_{4}$ by $6^{1}/_{4}$ inches, cloth, Swiss Frcs. 49.40. Reproduced by a photographic process from the first edition, this standard German work has been revised by inserting corrections in the text wherever possible, with a list of other corrections added after the contents pages. It deals with general principles of all electric machines and transformers and covers the design and performance of d-c electric machinery in detail.

GAS TURBINE THEORY. By H. Cohen and G. F. C. Rogers. Longmans, Green and Company, London, England; New York, N. Y.; Toronto, Ontario, Canada, 1951. 291 pages, charts, diagrams, $8^{3}/_{4}$ by $5^{3}/_{4}$ inches, cloth, $5.75. After an introductory chapter on the adaptability of the gas turbine, a comprehensive study of the performance of various cycles is developed, a chapter on gas dynamics introduces the reader to the relevant phenomena associated with high-speed flow and this is followed by an account of the methods of estimating the design-point performance of shaft-power gas turbines and turbojet engines. The work continues with chapters on the theory of centrifugal and axial compressors, combustion systems and turbines, and closes with an estimation of gas-turbine performance over the whole operating range.

INDUSTRIAL WASTES. By C. H. Lipsett. Atlas Publishing Company, 425 West 25th Street, New York, N. Y., 1951. 317 pages, tables, $9^{1}/_{4}$ by 6 inches, cloth, $5.00. A comprehensive survey of the field of important industrial wastes including their economic function and utilization in the industrial field. The discussion covers origins, collection methods, marketing procedures, recovery processes, and so forth. The wide range of subject matter includes plastics, chemicals, metals, textiles, rubber, paper, leather, wood, glass, and organic and agricultural wastes.

MATERIALS BUYING MANUAL. By H. A. Knight. Conover-Mast Publications, New York, N. Y.; Chicago, Ill.; 1951. 340 pages, charts, tables, $8^{3}/_{4}$ by 6 inches, linen, $4.50. Basic facts are given concerning a wide range of commodities used in industry covering general description, properties, production methods, commercial grades, uses, and the like. The relation of the particular commodity to the general scheme of the industry using it is indicated. Written primarily for industrial purchasing agents, the book is also useful as a general reference work.

MATHEMATICS FOR ENGINEERS. By R. W. Dull, revised and edited by R. Dull. Third edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1951. 822 pages, diagrams, charts, tables, $8^{1}/_{4}$ by $5^{1}/_{2}$ inches cloth, $7.50. Beginning with algebra and continuing through logarithms, determinants, the slide rule, trigonometric functions, calculus, and dimensional and similarity analysis, this work affords a convenient review of those phases of mathematics which are especially important in engineering work. It is intended either for use as a practical reference work or as a text for private study. A chapter on differential equations has been added, and other revisions have been made.

MECHANICAL MEASUREMENTS BY ELECTRICAL METHODS. By H. C. Roberts. Second edition. Instruments Publishing Company, Pittsburgh, Pa., 1951. 357 pages, illustrations, diagrams, $8^{1}/_{4}$ by $4^{1}/_{2}$ inches, cloth, $4.00. Methods are described in detail for electrically measuring displacements, pressure, vibrations, strain, accelerations, and so forth, including the basic principles of the circuits and systems. Capabilities and applications are discussed, and auxiliary devices—such as amplifiers, oscillographs, and calibrating devices—are dealt with as well as the main equipment. Several hundred footnotes and a supplementary bibliography indicate further available material in the field of electric gauging.

MODERN PLASTICS ENCYCLOPEDIA AND ENGINEER'S HANDBOOK, 1951. Plastics Catalogue Corporation, 575 Madison Avenue, New York 22, N. Y. 636 pages, illustrations, diagrams, charts, tables $11^{1}/_{4}$ by $8^{1}/_{2}$ inches, paper, $2.00. The new edition of this useful reference work differs considerably from the previous ones. The information which has become standardized is now omitted as it is available in the previous editions. This edition tells in detail what is new during the past year in plastics materials, applications, machinery, engineering, and techniques. The directory section contains not only buyers' guides for materials, equipment, and so forth, but also lists of trade associations, schools with courses on plastics, motion picture films on plastics, and trade names.

PRINCIPLES OF MECHANISM. By F. Dyson. Fourth edition. Oxford University Press, London, England; New York, N. Y.; Toronto, Ontario, Canada, 1951. 368 pages, diagrams, charts, tables, $8^{3}/_{4}$ by $5^{3}/_{4}$ inches, cloth, $3.00. This text aims to give a comprehensive presentation of the fundamental principles that apply to the moving parts of machines, adapted to the needs of students of engineering. Many worked-out examples of problems in velocity, acceleration, gearing, friction, belting, flywheels, governors, and balancing are given, together with a large number of problems for solution by the student.

PUNCHED CARDS, their Applications to Science and Industry. Edited by R. S. Casey and J. W. Perry. Reinhold Publishing Corporation, New York, N. Y., 1951. 506 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by $6^{1}/_{4}$ inches, linen, $10.00. The primary purpose of this book is to furnish sufficient information to the individual engineer, scientist, or technologist so that he may apply punched-card techniques to individual problems. The five parts of the book are: punched-card fundamentals; case histories of punched-card applications; general and fundamental considerations; future possibilities of applying mechanized methods to scientific and technical literature; and a bibliography on uses of punched cards.

(THE) SEAMLESS STORY. By J. P. Boore. Commonwealth Press, Los Angeles, Calif., 1951. 285 pages, illustrations, tables, $9^{1}/_{4}$ by 6 inches, fabrikoid, $5.75. A nontechnical history of seamless tubing, this book traces the evolution of tubing without seams or welds from its invention to contemporary mills. Biographies of inventors and important persons in the industry and information about companies are given. Included is an extensive bibliography listing patents, technical articles, and books.

SEMI-CONDUCTING MATERIALS. PROCEEDINGS OF A CONFERENCE HELD AT THE UNIVERSITY OF READING UNDER THE AUSPICES OF THE INTERNATIONAL UNION OF PURE AND APPLIED PHYSICS IN COOPERATION WITH THE ROYAL SOCIETY. Academic Press, Inc., New York, N. Y., 1951. 281 pages, charts, tables, 10 by $7^{1}/_{4}$ inches, cloth, $6.80. The papers included in this volume, constituting the proceedings of an international conference held in 1950, cover a wide range of topics from general discussions of energy states in impurity-activated semiconductors to studies of electronic and other characteristics of specific elements and semiconducting oxides. Brief French abstracts of the papers are included as well as lists of references to further sources of information. A complete list of symbols used is provided.

TIMESTUDY FUNDAMENTALS FOR FOREMEN. By P. Carroll. Second edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1951. 209 pages, illustrations, diagrams, charts, tables, $7^{1}/_{2}$ by 5 inches, $3.00. Step-by-step procedures are given from the beginning of a time study to the setting of standards from time-study data. Emphasis is placed on the actual value to be gained from time-study determinations and the reasons for each element in the procedure.

PAMPHLETS

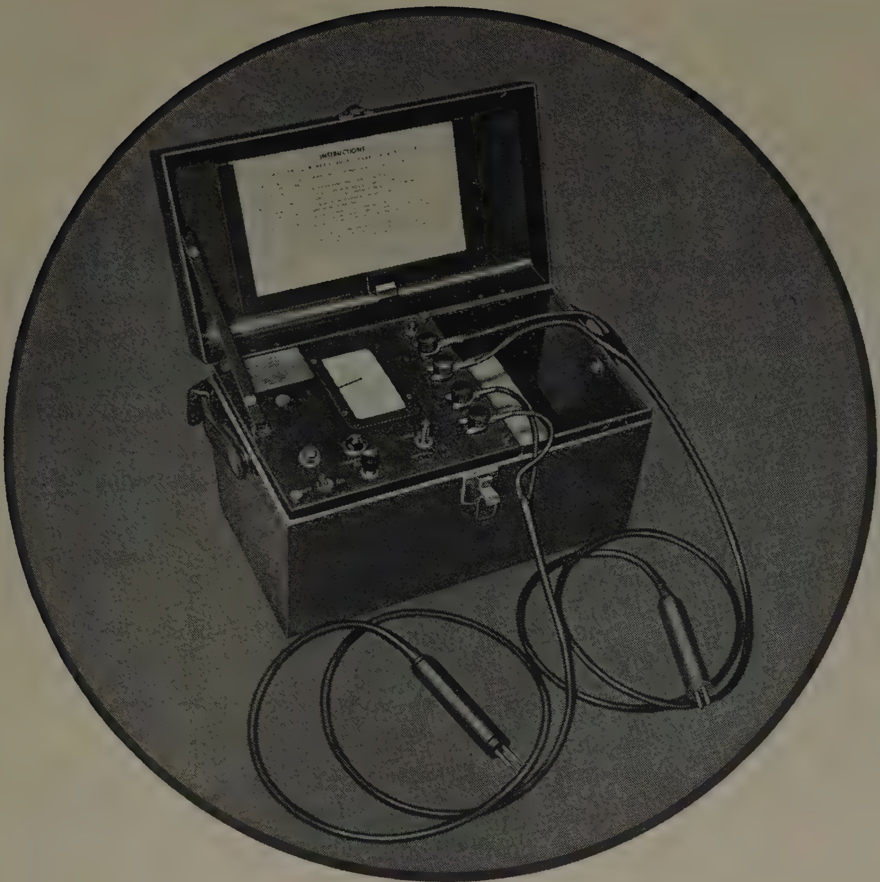
The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Industrial Uses of Radioactive Fission Products. To encourage further study by industry of the possibilities of use of fission products, the Atomic Energy Commission authorized the Stanford Research Institute to make this report available. Promising industrial applications for fission products are to be found in various stages of technological development, according to the report. Reviewed are technical problems involved in the design of processing plants to separate the fission products; in engineering the sources of radioactivity into a form suitable for various purposes; and in supplying fundamental knowledge on which to base development of industrial applications. Copies of the report may be obtained for $1.50 from Project 361, Stanford Research Institute, Stanford, Calif.

New NEMA Standards for Laminated Thermosetting Products, Publication Number *LP1-1951*. Information concerning the manufacture, test, and performance of laminated thermosetting sheets, rods, and tubes is covered. Data are given on paper, fabric, asbestos, glass and nylon bases grades, including three grades of engraving stock. The publication describes the grades and contains standards for form, color, finish, thickness, diameter, length, width, flexural strength, impact and bonding strength, water absorption, dielectric strength, dissipation factor, arc resistance, density, and compressive strength. $1.00 per copy. Available from the National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N. Y.

Instrument Servomechanisms. Presents basic terms and definitions used in the servomechanism field, explains the major components of servomechanism systems, the basic operational phenomena, and the characteristics of these systems. The text describes exclusively those servomechanisms used for automatic positioning. The behavior of servomechanisms systems is explained by analogy with the actions in electronic circuits. 265 pages, $2.00 per copy. Available from the Office of Technical Services, United States Department of Commerce, Washington 25, D. C.

Report of the Correlating Committee on Cathodic Protection. Published by the National Association of Corrosion Engineers as a service to industry, this report consolidates and revises the four bulletins prepared by the committee to aid in solving the problems created when adjacent underground metallic cables, pipe lines, and rail track are protected from corrosion by applied cathodic currents. The committee is composed of representatives of trade and professional organizations and large commercial institutions operating the principal underground metal plants in the United States. Copies available at 50¢ per copy from the National Association of Corrosion Engineers, 919 Milam Building, Houston, Tex.



This *NEW INSTRUMENT* Offers Greater Convenience in Field Use

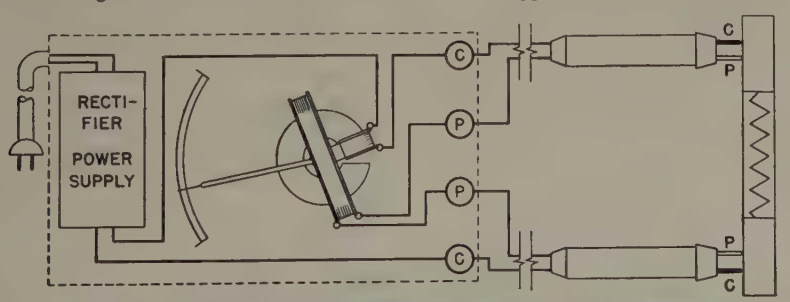
MEGGER® LOW RESISTANCE OHMMETER

This most recent addition to the Megger family of electrical resistance measuring instruments is a general purpose type with self-contained power supply. The set is available in two models, both having the same ranges of 0 to 1000 and 0 to 10,000 microhms. Model 1B carries batteries and Model 1R has a built-in rectifier which plugs into any ordinary lighting circuit outlet. Ample space is provided for the storage of all necessary leads and prods in a compartment of the same case.

The complete unit, with either battery or rectifier weighs only about 19 pounds. It is, therefore, easily portable and convenient to use in the field.

Write for Bulletin 24-46 EE which describes these new instruments completely.

Schematic diagram of electrical connections for the Megger Low Resistance Ohmmeter



JAMES G. BIDDLE CO.

• ELECTRICAL TESTING INSTRUMENTS
• SPEED MEASURING INSTRUMENTS
• LABORATORY & SCIENTIFIC EQUIPMENT

1316 ARCH STREET
PHILADELPHIA 7, PA.

BIDDLE *Instrument News*

"CABLE-FAULT LOCATING PRACTICES IN PHILADELPHIA"

That is the title of an article which appeared in a recent issue of Electric Light and Power Magazine. It was written by R. S. Diggs, Assistant Superintendent, Service Maintenance Section, Philadelphia Division, Electric Transmission and Distribution Department of the Philadelphia Electric Company.

Mr. Diggs discusses the three methods of locating cable faults used on his company's underground power systems, the a-c method, the thyratron, and the impulse method.

We have obtained a limited supply of these reprints and will be glad to supply them to interested individuals so long as the supply lasts. Check Bulletin 65 P1 EE on the coupon below.

USERS FIND BIDDLE TTR SETS INDISPENSABLE

There have been a lot of mighty fine things said about our Transformer Turn Ratio Test Set in the two years we have been producing them. But nothing we have heard compares with the comments we have been hearing lately.

Since the announcement of Model 3 we have had requests for modification of several earlier models. It is gratifying to receive comments like:

"We hope that the change-over will not require too much time as this instrument is in daily use on our test floor." and:

"Our instrument is used constantly by the testing department and is such a timesaver that we want to have it back in service as soon as possible."

We would like to quote all the things that have been said about this unique instrument but space does not permit. We urge those who have not investigated the TTR Set to do so by writing for Bulletin 55 EE which describes it in full.

James G. Biddle Co.
1316 Arch St., Philadelphia 7, Pa.

Gentlemen:
Please send me items checked:

☐ 24-46 EE ☐ 65 P1 EE ☐ 55 EE

NAME

JOB FUNCTION

COMPANY

ADDRESS

INDUSTRIAL NOTES ....

RCA Names Director of Research, Two Vice-Presidents. Dr. Irving Wolff has been named Director of Research for the RCA laboratories division of the Radio Corporation of America, and Robert L. Werner and Ernest B. Gorin have been elected Vice-Presidents of the corporation.

Ohmite to Build Larger Plant. Plans for a new and larger manufacturing plant, located at 3601 Howard Street, Skokie, Ill., have been announced by the Ohmite Manufacturing Company of Chicago. The new plant will provide enlarged facilities for the company's increased defense production.

U. S. Steel Concludes Venezuelan Contract. The United States Steel Corporation has concluded a contract between the Venezuelan Government and the Orinoco Mining Company, a United States Steel subsidiary, for the dredging and maintenance of a ship channel through the Macareo and Orinoco rivers in Venezuela. This channel will permit ocean-going ore carriers to proceed directly from the ocean to the loading dock to be installed by the mining company at the river terminal of its 90-mile railroad extending from the company's ore mines at Cerro Bolivar to the Orinoco River. It is hoped that the first shipments of iron ore can be made to the United States from Venezuela early in 1954.

Executive Changes at Burndy Canada, Ltd. In a move to expand and streamline the facilities of Burndy Canada, Ltd., the company has announced the following personnel additions and changes. Bryce Kell, formerly eastern district manager, has been made general sales manager; Fred W. Patterson has joined the company as eastern district manager in Montreal, succeeding Mr. Kell; Jack K. Harding has joined the Montreal staff to work under supervision of Mr. Patterson; and Roy Bunston, formerly chief sales engineer, has been made chief engineer.

Wolff to Direct Centralab Engineering. Robert L. Wolff has been made Director of Centralab Products Engineering.

McGraw Acquires Jeffrey-DeWitt Insulator Corporation. The McGraw Electric Company has acquired the Jeffrey-DeWitt Insulator Corporation, Kenova, W. Va., from W. L. Stinson, President. The Line Material Company, Milwaukee, Wis., a division of McGraw, will operate the new facility under the management of Mr. Stinson. Jeffrey-DeWitt will provide the Line Material Company's ten plants with substantial quantities of electrical porcelain for use in the manufacture of its transmission and distribution equipment.

Weston Appointment. Anthony H. Lamb has been made Vice-President in charge of manufacturing of the Weston Electrical Instrument Corporation. Mr. Lamb succeeds Reginald R. Lambe who has retired after 35 years of service. Weston also has announced the retirement of Leroy C. Nichols, their New York district manager for 34 years.

Vice-President and Treasurer of Emerson Retires. William S. Snead, Vice-President and Treasurer of The Emerson Electric Manufacturing Company, has retired, but will continue to serve as a Director of the company. Ralph E. Petering will assume the duties of Vice-President and Treasurer, succeeding Mr. Snead.

Pacific Electric Appointment. R. W. Hutchinson has been appointed eastern division manager of the Pacific Electric Manufacturing Corporation, succeeding E. S. Kessler, who passed away recently.

American Steel and Wire Retirement. Frank E. Chesney, purchasing agent and a Director of the American Steel and Wire Company, has retired after nearly 40 years of service with the company.

Crane Company Enters Aviation Field. The Crane Company, Chicago, Ill., manufacturer of valves and fittings, has entered the aviation industry through acquisition of assets formerly owned by Hydro-Aire, of Burbank, Calif. Hydro-Aire is a major manufacturer of valves, filters, and actuators for aircraft and engine manufacturers.

Sylvania Appointments. Sylvania Electric Products, Inc., has appointed David G. Christie as Director of employee services, and Lawrence P. Pleasants as merchandising manager, lamps, of their lighting division.

Chicago Lighting Institute Elects Officers. Gilbert K. Hardacre, manager of commercial sales, Public Service Company of Northern Illinois, has been re-elected President of the Chicago Lighting Institute; A. G. Nelsen, Chicago district manager, lamp division, Westinghouse Electric Corporation, was elected Vice-President; E. J. Doyle, Jr., assistant sales manager, Commonwealth Edison Company, was elected Secretary-Treasurer; and C. W. Zerson, managing director, Chicago Lighting Institute, has been re-elected assistant Secretary-Treasurer.

Electronic Devices Appoints Technical Director. Frank H. Edelman, formerly chief chemist of the International Resistance Company, has been made technical director of the resistor division of Electronic Devices, Inc.

Minnesota Mining Names Three to Director Posts. Dr. J. O. Hendricks has been promoted to the newly created post of associate director of the Minnesota Mining and Manufacturing Company's

(*Continued on page 24A*)

(*Continued from page 18A*)

central research laboratories. Dr. Matthew W. Miller and Dr. H. M. Scholberg have been named assistant directors also.

Continental Electric Elects Vice-President. Paul M. Hafer has been elected Vice-President in charge of engineering of the Continental Electric Equipment Company.

Delta-Star Names Works Manager. The Delta-Star Electric Company, a division of the H. K. Porter Company, Inc., has named J. C. Hydrick as works manager.

G-E News. Brigadier General Tom C. Rives (retired) has been appointed manager of the newly established General Electric Company's advanced electronic center at Cornell University, Ithaca, N. Y. General Electric has also named S. Vernon Travis manager, sales standards section, apparatus sales division; Edward A. Green, manager of product planning, Small and Medium Motor Department; C. G. Klock as manager of finance, air conditioning division; and Louis H. Albee, manager of advertising and sales promotion for the Rocky Mountain district, apparatus sales division. The company has also announced the retirement, after 43 years of service, of Neil Currie, Jr., general consultant, manufacturing services division.

International Rectifier Buys New Plant. The International Rectifier Corporation has purchased a new factory building at 1521 East Grand Avenue, El Segundo, Calif. The plant now occupied in Los Angeles will be maintained for research and development. General sales and administrative offices will be located at the new plant in El Segundo, to which all future correspondence should be directed.

Neff New Stackpole Sales Manager. A. K. Neff has been made sales manager of the Stackpole Carbon Company.

Glass Fibers, Inc., Purchases Controlling Interest in Vidradamp. Glass Fibers, Inc., of Toledo, Ohio, has purchased controlling interest in the Vidradamp Corporation of California, manufacturer of "Vibraglass" products.

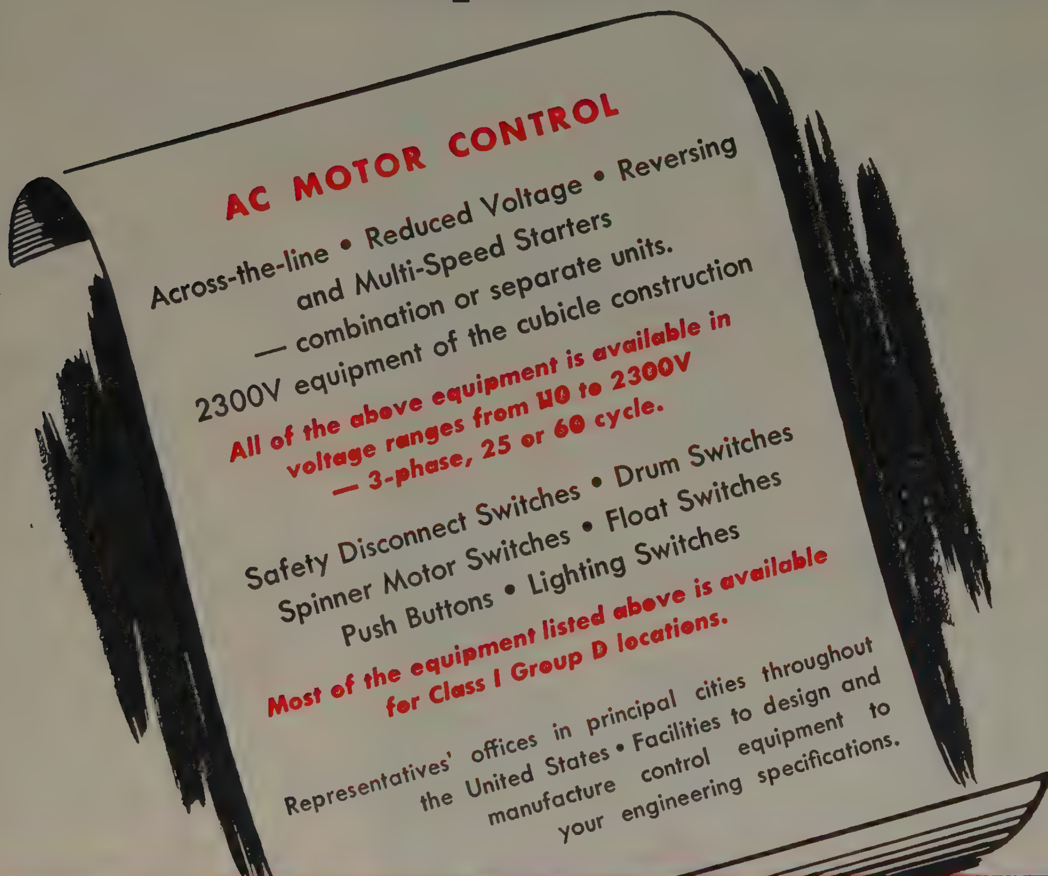
Sprague Opens Ohio Offices. The Sprague Electric Company has opened an application engineering office at 3 East Second Street, Dayton, Ohio. William M. Lana will head the new office.

Duro-Test Purchases Jewel Products Corporation. The Duro-Test Corporation, incandescent and fluorescent light bulb manufacturer, has purchased complete ownership of the Jewel Products Corporation, manufacturers of incandescent lamps. Jewel will be operated as a wholly owned subsidiary under its same name, with Gustav Herzberg, cofounder, as President.

(*Continued on page 28A*)

Oil Immersed

. . . . for dependable service and long life under adverse atmospheric conditions . . . .



ROWAN CONTROL

THE ROWAN CONTROLLER CO., BALTIMORE, MD.

(*Continued from page 24A*)

RCA Victor Appointments. W. L. Rothenberger has been made manager of the Eastern region for the RCA Victor Division, Radio Corporation of America; R. M. Macrae, manager of the newly formed Northeastern region; and William F. Carolan has been appointed general sales manager of the newly created Air-Conditioning Department.

NEW PRODUCTS

Low-Cost Locomotive. A new low-cost electric locomotive which can handle main-line freight traffic on nearly 90 per cent of America's electrified lines has been developed by the General Electric Company. Designed for quantity production, this single-phase, a-c locomotive has dynamic braking, and operates from 11,000-volt 25-cycle single-phase a-c trolley wire. The streamlined cab carried on two 2-axle swivel trucks is similar to the diesel-electric freight locomotives. Each unit has a continuous rating of 2,500 horsepower, and can develop as much as 5,000 horsepower for short periods. As many as four units can be operated in multiple under the control of one engineer. Further information will be supplied by the News Bureau, General Electric Company, Schenectady 5, N. Y.

New Winding Arrangement for Single-Phase Motors. The Hutchins Electric Company, Inc., Ridgeway, Pa., has announced the development of a new winding arrangement for single-phase motors which reduces total copper requirements by about 25 per cent. The need for a separate starting winding is eliminated by utilizing a section of the running winding for starting purposes. During the running period the entire winding is active. Shaft-mounted fans, blowers, and pumps are contemplated as early applications. The winding, in all cases, is of large-diameter wire which minimizes the possibility of burnouts due to excessive heating during the starting period and makes machine winding practical throughout. Further details may be obtained from the Hutchins company.

Special Effects Amplifier. The RCA Victor Division has developed a special effects video amplifier which can accomplish electrically fades, dissolves, superpositions, wipes, insertions, and other television picture combinations at microsecond speed. It is expected to displace optical and mechanical techniques used to achieve these effects. The RCA system consists of a single rack-mounted unit which accepts the two video or picture signals to be mixed, together with a masking signal, and delivers the desired composite signal. The relationship between the two video signals is controlled by the masking signal, which may be delivered by a television camera of virtually any type—field, studio, film, or flying spot—or a generator of synthetic signals. The

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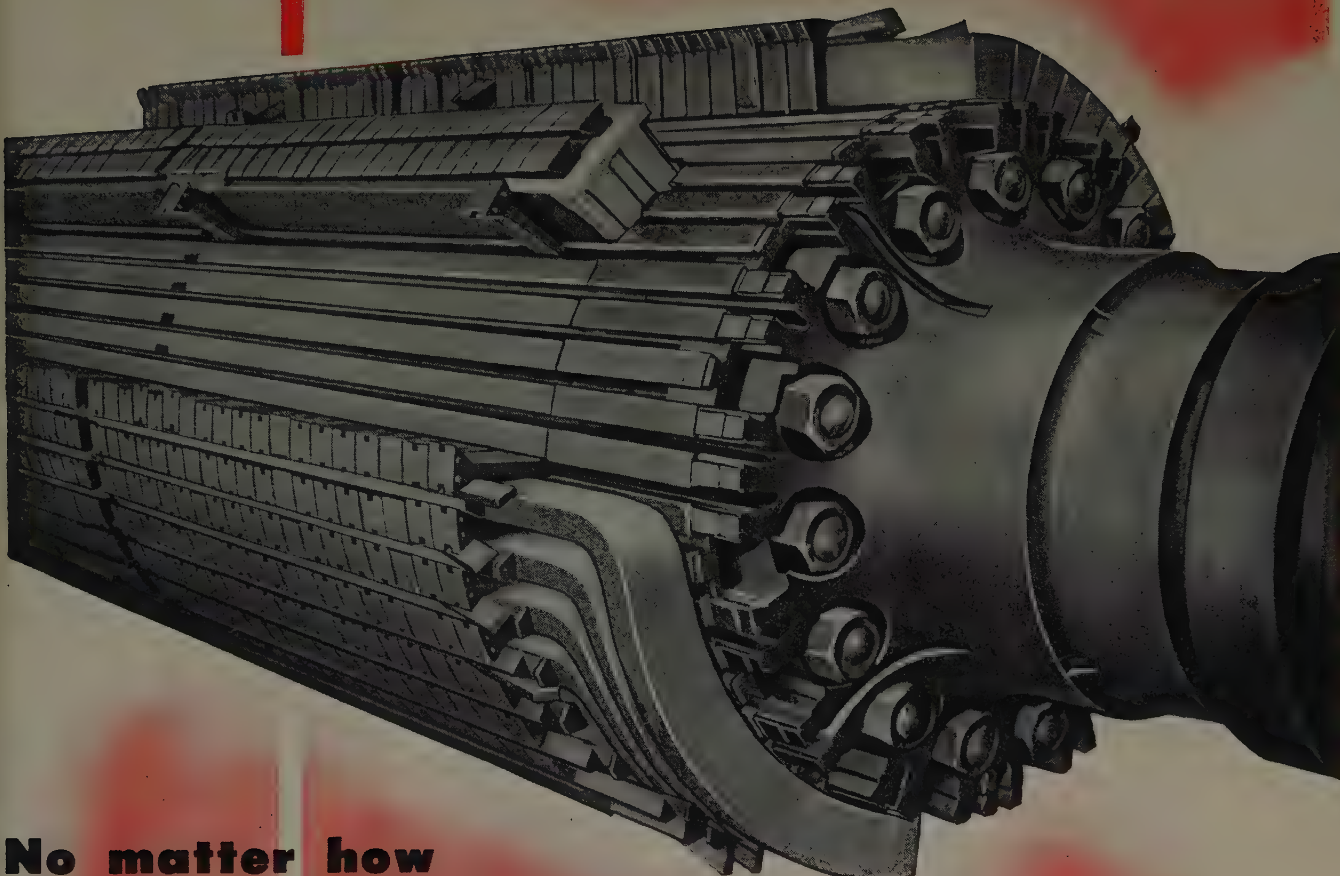


No matter how unusual your generator may be . . .

we can build New-Born Power into it!

Peculiarities of design such as those in the turbo-alternator rotor above, photographed in our shop, hold no terrors for National Electric Coil engineers. In this case, removable tooth-sections allow the field coils to be hot-pressed and seasoned as a complete coil unit. Each finished coil is placed on the rotor core and the tooth-sections are inserted. National is prepared, by experience and equipment, to take advantage of every opportunity afforded by design and construction to give you maximum power and life. *Now* is the time to make sure your rotating electrical equipment is ready for the job which lies ahead. Write or wire (or cable Natcoil, Columbus).

NATIONAL ELECTRIC COIL COMPANY

★ COLUMBUS 16, OHIO, U. S. A. ★

ELECTRICAL ENGINEERS: MAKERS OF ELECTRICAL COILS AND INSULATION— REDESIGNING AND REPAIRING OF ROTATING ELECTRICAL MACHINES

TRADE MARK

(*Continued from page 28A*)

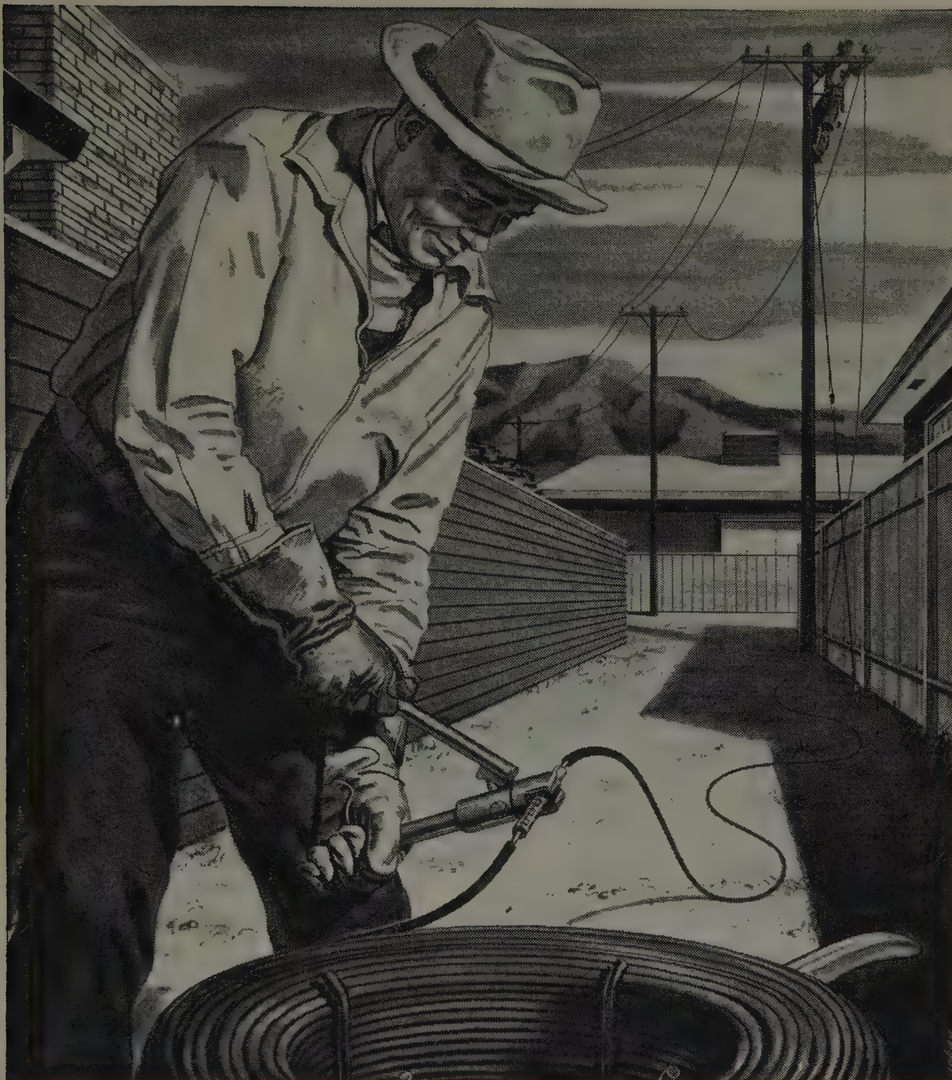
masking signal is used to operate two electronic switching circuits in the channels carrying the two picture signals to be mixed. When the masking source scans black, one picture signal is transmitted, and when it scans white, the other signal is transmitted. The effects and mask shapes are limited only by the imagination of the producer or program director. The RCA Victor Division, Radio Corporation of America, Camden, N. J., will supply any additional details.

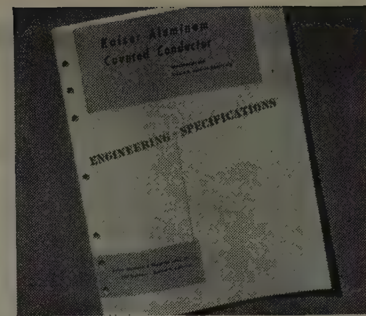
Explosion-Proof Lamp Unit. The Hanovia Chemical and Manufacturing Company, 100 Chestnut Street, Newark 3, N. J., has announced development of a new explosion-proof germicidal unit designed for use in hazardous areas, where ultraviolet lamps are required for the elimination of air-borne organisms. The unit is designed for wall or ceiling mounting to furnish direct or indirect irradiation; ultraviolet energy is furnished by two hairpin-shaped lamps. Further information is available from the Germicidal Equipment Division of the company.

Servo Amplifiers. Servomechanisms, Inc., has announced the availability of two new servo amplifiers featuring a hermetically sealed, oil-filled packaging technique. This packaging technique provides greater heat dissipation and elimination of hot spots, longer tube life, greater resistance to vibration and shock, and a great saving in space. Designated as type *SA104H* and type *SA112H*, these 400-cycle servo amplifiers supply outputs of 9 watts at 115 volts and 3 watts at 30 volts, respectively. The type *SA104H* has been designed primarily for use in high-performance servo loops and incorporates a derivative control network, and the *SA112H* is intended for use in analogue computer servo loops and is designed for velocity damping, furnished by a tachometer generator. Both are miniaturized plug-in units, in which all the electronic elements required for one function in a control system are packaged together. Engineering bulletins on these amplifiers are available from Servomechanisms, Inc., Post and Stewart Avenues, Westbury, L. I., N. Y.

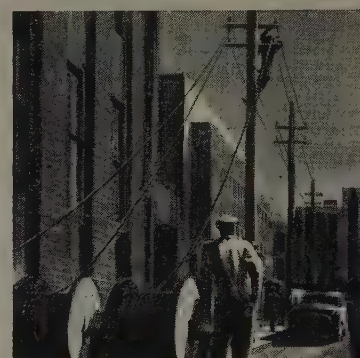
Noise Analyzer. An octave-band analyzer for noise measurements developed by the General Radio Company can be used for determinations of loudness, speech-interference level, articulation index, airplane comfort level, and in other problems involving the reduction of noise to produce comfort or ear protection. It also can be used in the determination of the sound-transmission loss of building walls, partitions and floors, and as a selective bridge detector or filter. Eight passbands are provided; the lowest is a low-pass filter and the highest a high-pass filter; the middle six, covering from 75 to 4,800 cycles, are each an octave in width. The initial rate of attenuation beyond cutoff of the band-pass sections is about 50 decibels per octave. An amplifier, cali-

(*Continued on page 48A*)





FREE BOOKLET—Gives complete engineering data on the new Kaiser Aluminum Conductor. Includes both weatherproof and self-supporting conductor. Send for it today!



MORE ADVANTAGES—Neoprene covering on Kaiser Aluminum Weatherproof Conductor is abrasion resistant, fungi resistant . . . and there's no festooning as with conventional textile coverings.

HIGHEST QUALITY—Our production personnel have had long experience in the conductor field, employ the finest production facilities. Conductor is tested by the most modern instruments.

This line means lower costs, longer life!

When you install Kaiser Aluminum Weatherproof Conductor for distribution lines or service drops you cut costs by 20 to 30 per cent.

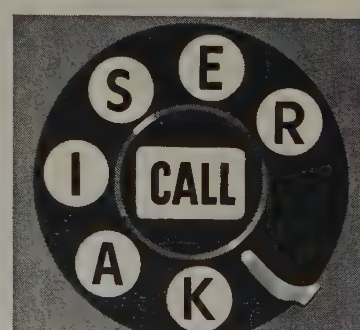
Here's why:

1) First cost is lower than with copper. 2) Reduced weight—approximately half that of copper—permits longer spans, speeds installation. 3) Diameters are smaller than the usual triple braid weatherproof, reducing ice and wind loads, relieving tension on house and pole.

Good splices and taps are assured because Kaiser Aluminum Weatherproof Conductor is clean stripping. The neoprene covering is smooth, homogeneous, seamless, thus resists moisture.

Call us today for all the facts. 65 Kaiser Aluminum offices and warehouse distributors in principal cities. Kaiser Aluminum & Chemical Sales, Inc., Oakland, Calif.

Also distributed by: General Electric Supply Corporation, Line Material Company, Mine & Smelter Company, Tafel Electric and Supply Company, Westinghouse Electric Supply Company.



TECHNICAL ASSISTANCE—For help on your conductor problems, call any Kaiser Aluminum office. It's listed in your local classified telephone directory.

Kaiser Aluminum

Setting the pace . . . through quality and service

(*Continued from page 38A*)

brated attenuator, and indicating meter in the instrument make it possible to measure octave-band levels over a range of about 60 decibels. A level control is provided to set the gain of the amplifier, with input levels between 1 and 10 volts. The analyzer is designed to operate from the output of a standard sound-level meter; for levels above 70 decibels, it can be operated directly from a microphone. The General Radio Company, 275 Massachusetts Avenue, Cambridge 39, Mass., will supply any further information desired.

Shirt-Stud Capacitors. The "shirt-stud" capacitor is a new 1/4-inch ceramic design for coupling ultrahigh-frequency circuits in television receivers and other electronic equipment. Developed by the Sprague Electric Company, North Adams, Mass., the capacitor is fitted with hollow connections to accommodate leads or pins from subminiature electron tubes. Available capacitance values range up to 22 micromicrofarads at 500 volts d-c working. Complete engineering information is contained in Sprague engineering bulletin *605*, available on request.

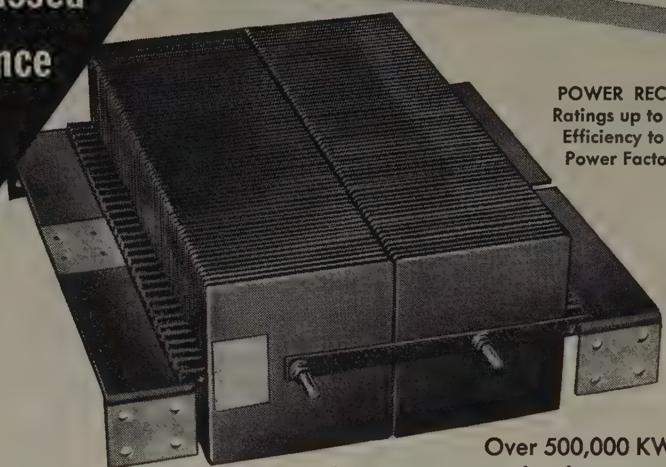
Phantom Repeater. The Keithley Instruments model *102* phantom repeater is a new type of instrument designed to increase the speed and accuracy of electrical measurements. It features a circuit with an input impedance of 200 megohms, shunted by 6.5 micromicrofarads at the ends of the test leads, coupled with an instrument amplifier having a low output impedance of 350 ohms in series with 20 microfarads. Thus, when the new repeater is connected between the unknown circuit and the test instruments, it permits accurate, simultaneous use of both the voltmeter and oscillograph. The entire system is linear—the input voltage is repeated exactly at the output, except for increases in level selected by the operator. The entire input circuit of the phantom repeater is enclosed in a shield which is driven at almost the same instantaneous potential as the test signal conductor. The circuit being tested therefore has to supply only a fraction of the usual charge, thus greatly reducing the apparent capacitance. Similarly, only a fraction of the usual current flows through the conducting paths, greatly increasing the apparent resistance. Undesirable electrostatic fields are eliminated by enclosing the driven shielding in a second cable shield and by the metal cabinet, which are maintained at ground potential. Power supply is 110 to 120 volts, 50 to 60 cycles per second, 60 watts. Line voltage variations from 103 volts to 125 volts cause less than 2-per cent change in gain. Any additional information may be obtained from Keithley Instruments, 3868 Carnegie Avenue, Cleveland 15, Ohio.

Motor Control Center. A new motor control center for use wherever two or more a-c motors (up to 200 horsepower, 600 volts) are controlled from a central location has been announced by General

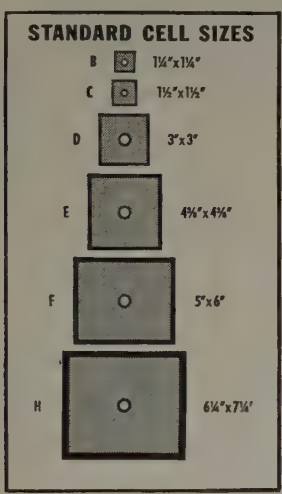
(*Continued on page 52A*)

International Selenium Rectifiers

for unsurpassed performance



POWER RECTIFIERS
Ratings up to 250 KW
Efficiency to 87%—
Power Factor 95%



Over 500,000 KW, DC Power, is operated with *International* Selenium Rectifiers. A recent month's production included Rectifiers to supply 40 microamperes, 1,000 volts, and Rectifiers with a capacity of 140,000 amperes, 14 volts. Designed and built to meet Government Specifications. Manufactured for temperatures up to 100° C ambient—100% humidity. Owned and managed by Engineers who are specialists in the design and manufacture of Selenium Rectifiers. Submit your problems for analysis and we will be glad to offer our recommendations.

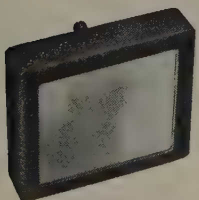
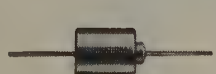
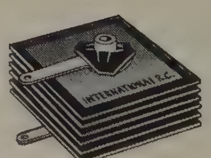


Photo-Electric Cells
Self-Generating Type
Output up to 600 microamperes at 100 foot-candles illumination and 100 ohms external resistance.



Hermetically Sealed Rectifiers
Cartridge Type—up to 60 ma., 9,000 volts per cartridge.

High-Voltage Rectifiers
Cartridge Type—up to 60 ma., 9,000 volts per cartridge.



Miniature Rectifiers
From 65 to 1,000 ma.

GENERAL OFFICES:
1521 E. Grand Ave.
El Segundo, Calif.
Phone El Segundo 1890

CHICAGO BRANCH OFFICE:
205 W. Wacker Dr.
Franklin 2-3889

(*Continued from page 48A*)

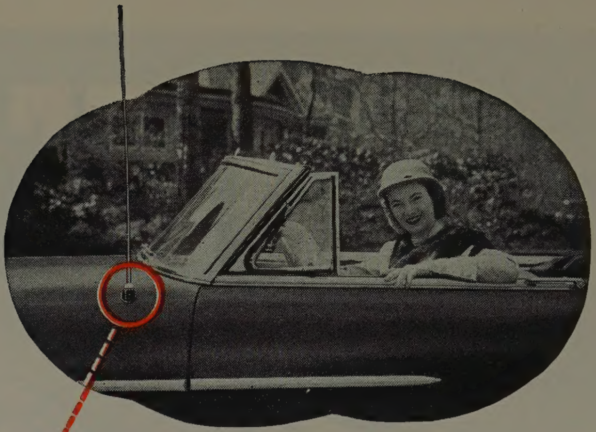
Electric's Control Department. The new center, pre-engineered, factory-wired and assembled, was developed for use in power stations, public buildings, paper mills, chemical, petroleum, steel, rubber, ore, food, and other processing plants. It provides a simplified method of installing and servicing in a central location a-c combination motor starters in National Electrical Manufacturer's Association sizes 1 through 5, as well as lighting panels and associated equipment for a group of motors. The center is designed to withstand short-circuit stresses up to 25,000 amperes. One of the main features of the new design is a 4-inch vertical trough (with cable supports) which runs the full length of each section, providing ample space for continuous wiring. Additional information on the motor control center is contained in publication *GEA-4979A*, which is available from the General Electric Company, Schenectady 5, N. Y.

Shaft-Position Indicator. A precision shaft-position indicating system which detects the angular position of a rotating shaft and converts the resulting indications to a digital representation has been developed by Engineering Research Associates, Inc., 1902 West Minnehaha Avenue, St. Paul W4, Minn. Called the shaft-monitor, the new device consists of two major components, an electromechanical locator unit which couples to the reference shaft and an electronic converter unit. The monitor utilizes a magnetic recording mechanism to indicate on command (and as often as 20 times per second) the position of a reference shaft. Accurate to ±0.09 degree, shaft-monitor measurements may be routed to a convenient remote location and displayed as visual indications in digital form, transferred to magnetic tape, punched tape, or punched cards for future analysis, or used to perform desired control functions. An illustrated booklet describing the shaft-monitor may be obtained by writing Department A of the company.

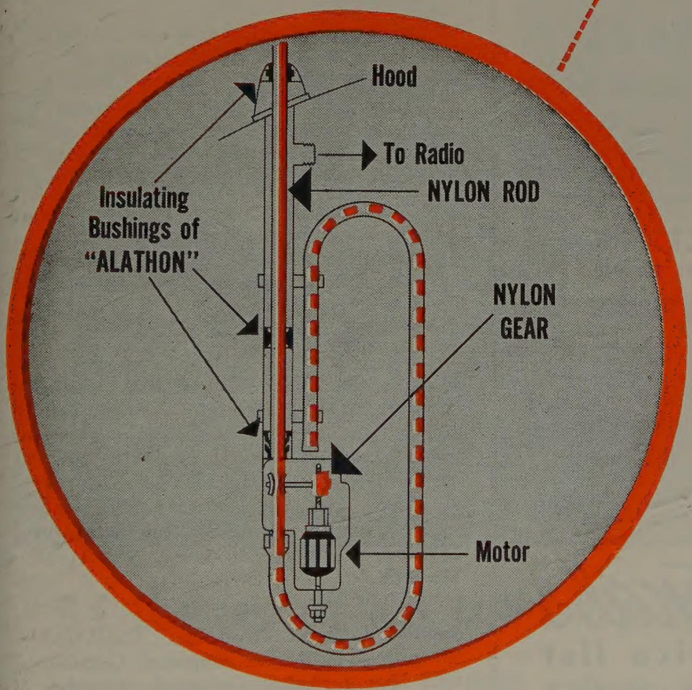
Boltaron. A new plastic material, weighing approximately one-sixth the weight of stainless steel and with greater corrosion resistance, has been produced by Bolta Products, Inc. Boltaron *6200* is a rigid nonplasticized polyvinyl chloride of high molecular weight. It is being distributed in the form of sheets, rods, fabricated parts, fittings, and molding compounds. In industrial processes where acid corrosion and oxidation below 165 degrees Fahrenheit are basic problems, Boltaron *6200* can replace such critical materials as stainless steel and rubber. It may be welded, molded, extruded, fabricated, and even machined after welding, which is not possible with metals. Further details are available from Bolta Products, Inc., Lawrence, Mass.

Jet Engine Starter. An automatic jaw meshing mechanism developed by Jack and Heintz, Inc., eliminates a potential source of trouble in jet engine starters—failure of the d-c solenoid. The new

(*Continued on page 56A*)



New Packard antenna design employs two Du Pont plastics



When driver pushes button, motor-driven worm gear turns nylon gears, which turn spring-loaded pulleys. Nylon rod is driven up by pulleys, forcing "live" members upward. Rod coils into trombone-like shape (dotted line) when antenna is lowered. (*Automatic antenna used on 1951 Packards made by Casco Products Corp., Bridgeport, Conn.*)

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DEPARTMENT
PLASTICS • CHEMICALS

Nylon plastic and "Alathon" polythene resin meet mechanical and electrical requirements for automotive antenna

Two Du Pont plastics materials—nylon and "Alathon"* polythene resin—are playing key roles in the success of this new motor-driven antenna used on Packard automobiles. A 4½-foot flexible rod which raises and lowers the "live" members is made of nylon, as are the two gears that transmit power from the motor to pulleys which drive the rod upward and downward. Insulating bushings, which must have very low moisture-absorption and excellent dielectric properties at radio frequencies, are molded of "Alathon."

The rod must have an unusual combination of properties. Most important of these: it must be rigid enough to force the antenna up and down, yet flexible enough to fold into a trombone-like position when the antenna is down; and it must also have good dielectric properties. Only nylon was found to meet the mechanical requirements, while at the same time maintaining a high "Q" and low capacity. The nylon rod and gears have been subjected to as many as 80,000 cycles—many more times than they could possibly be called on to withstand during the life of any car. Neither shows any sign of wear.

Both nylon and "Alathon" are finding a number of uses in molded parts for electrical equipment, in addition to their many well-known applications in wire and cable. Nylon is used in such items as coil forms, insulator bushings, grommets, motor slot liners, switch components . . . "Alathon" in radio and television parts, potting compounds, etc.

For additional information about nylon, "Alathon" and other Du Pont plastics, write:

E. I. du Pont de Nemours & Co. (Inc.),
Polychemicals Dept., District Offices:
350 Fifth Avenue, New York 1, New York
7 S. Dearborn St., Chicago 3, Illinois
845 E. 60th St., Los Angeles 1, California

(*Continued from page 52A*)

D31-1 starter incorporates a friction ring jaw mesh arrangement instead of the d-c solenoid usually used to secure jaw meshing action. This starter will always produce positive meshing as long as sufficient electric power is available to rotate the unit's armature. The mechanism consists of a phosphor bronze friction ring which restrains jaw rotation and permits a cam to ride down a ramp to extend the starter jaw. As the jaw moves out, tension on the friction ring decreases. At full extension, there is no tension of the ring on the jaw. The constant current, variable voltage starter is rated at 0 to 30 volts d-c, 1,000 amperes, 800 rpm, 20 to 1/2 horsepower. Further information is available from Jack and Heintz, Inc., 17600 Broadway, Cleveland 1, Ohio.

TRADE LITERATURE

Measuring Equipment. A new 80-page catalogue, *GEC-1016*, summarizing all of the General Electric Company's testing and measuring equipment for laboratory and production line use, has been announced as available upon request from the company at Schenectady 5, N. Y.

Air Tools. A 76-page catalogue covering the complete line of Aro industrial air tools and accessories may be obtained upon request to the Aro Equipment Corporation, Bryan, Ohio.

Metallic Rectifier Design. An article entitled "Metallic Rectifier Design and Application," written by Julian Loebenstein of the Radio Receptor Company, Inc., has been released in booklet form, and is available from the company addressed to the attention of the Seletron Rectifier Division, 251 West 19th Street, New York 11, N. Y.

Steatite Ceramic Products. Catalogue *951* published by the Stupakoff Ceramic and Manufacturing Company, Latrobe, Pa., contains information and dimensions on principal steatite products. It may be obtained upon request.

Identification of Metals and Alloys. The Development and Research Division of The International Nickel Company, Inc., 67 Wall Street, New York 5, N. Y., has issued a 48-page booklet on the rapid identification (spot testing) of more than 125 metals and alloys, as an aid to scrap salvage. The booklet is available without charge from the company.

High-Frequency Insulators. Bulletin *512*, issued by the American Lava Corporation, contains *JAN-I-8* numbers cross-indexed with American Lava numbers on AlSiMag high-frequency insulators. This enables the prompt location of the exact insulators required. Copies of the bulletin are offered by the American Lava Corporation, Chattanooga 5, Tenn.

(*Continued on page 62A*)

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G-E Bulletins. The General Electric Company has listed as available the following new bulletins: *GEA-5679* on induction heating; *GEA-5556* on electric drives for stock preparation; *G93-136*, on 2-way frequency-modulation radio communication equipment for civil defense; *GEA-5478* on electrical modernization of cement plants; and *GEA-5660* on electronic contour follower systems. All publications may be obtained upon request to the General Electric Company, Schenectady 5, N. Y.

High-Temperature Magnet Wires. The Sprague Electric Company of North Adams, Mass., has announced as available a new bulletin, number *401-A*, containing notes on the design and processing of coils wound with ceroc magnet wires.

Magnetic Motor Starters. The Arrow-Hart and Hegeman Electric Company has issued a folder which describes their line of *RAS* and *RAR* multispeed and reversing magnetic motor starters. The folder may be obtained from the company at 103 Hawthorn Street, Hartford 6, Conn.

Electric Wiring Devices. A 40-page catalogue on electric wiring devices, number *57*, has been announced as available by the Rodale Manufacturing Company, Inc., Emmaus, Pa.

MCF Diffusion Pumps. A new data sheet which describes and charts the characteristics of type *MCF* diffusion pumps is offered by Distillation Products Industries, division of Eastman Kodak Company, Rochester 3, N. Y.

Relay Catalogue. A relay catalogue describing the complete line of Amrecon relays is available from American Relay and Controls, Inc., 4939 West Flournoy Street, Chicago, Ill.

Industrial Battery Maintenance. Gould-National Batteries, Inc., has initiated a "Plus Performance Plan" whereby a library of information on how to select, charge and handle, maintain, and determine the condition of industrial storage batteries used in industrial trucks, railroad air-conditioning and car-lighting, railroad signalling, telephone systems, alarm systems, and utilities is available without charge to industrial battery users from the company at 467 Calhoun, Trenton 7, N. J.

Switch and Outlet Box Guide. A new switch and outlet box guide, in the form of a wall chart, has been issued by General Electric's construction materials division. The chart gives box catalogue numbers, sizes, and information on number and sizes of conductors permitted in each box. Additional information on boxes is reprinted from the National Electrical Code. The chart, number *18-87*, is available from the Construction Materials Department, General Electric Company, Bridgeport 2, Conn.